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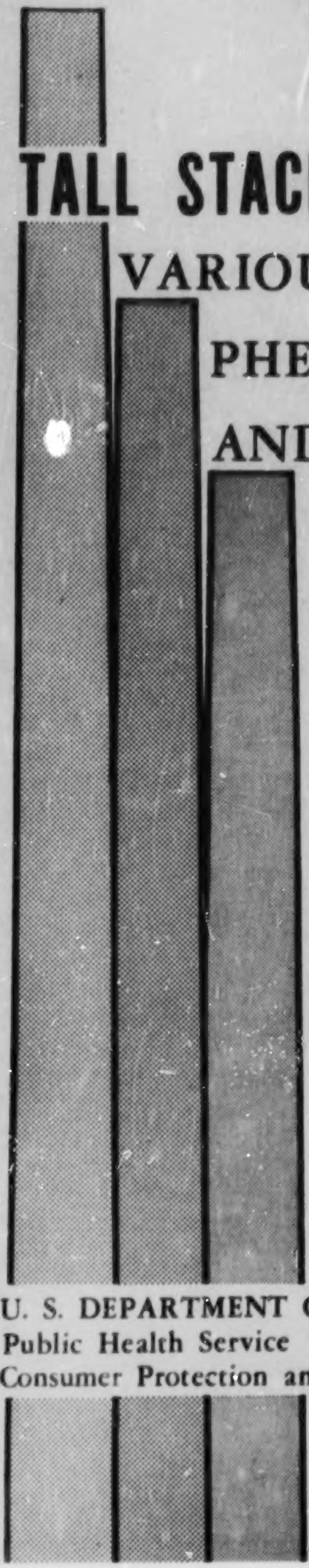

TALL STACKS,
VARIOUS ATMOSPHERIC PHENOMENA, AND RELATED ASPECTS

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
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10542

STANDARD TITLE PAGE FOR TECHNICAL REPORTS	1. Report No. APTD 69-12	2. Govt. Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle
TALL STACKS, Various Atmospheric Phenomena, and Related Aspects

5. Report Date
May 1969

6. Performing Organization Code

7. Author(s)

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Consumer Protection and Environmental Health Service
National Air Pollution Control Administration
Arlington, Virginina

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Agency Name and Address
SAME

13. Type of Report & Period Covered

14. Sponsoring Agency Code

15. Supplementary Notes
The APTD series reports technical data of interest to a limited readership.

16. Abstracts

Dispersion from tall stacks is discussed. Then a bibliography of 214 abstracts of documents currently in the information retrieval system of the Air Pollution Technical Information Center is presented. The abstracts are arranged in three major sections: Tall Stacks; Atmospheric Phenomena; and Miscellaneous. Within each section, they are alphabetized by author. Most date from the late '60's, however the earliest is dated 1949.

17. Key Words and Document Analysis. (a). Descriptors
Air pollution
Chimneys
Atmospheric diffusion
Plumes
Bibliographies

17b. Identifiers/Open-Ended Terms
Tall stacks

17c. COSATI Field/Group 13/02, 04/01, 05/02

18. Distribution Statement Unlimited	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 103
	20. Security Class. (This Page) UNCLASSIFIED	22. Price

FORM NBS-867(1-70)

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Arlington, Virginia
May 1969

CONTENTS

DISPERSION FROM TALL STACKS 1
  INTRODUCTION 1
  STATEMENT OF THE PROBLEM 1
  GROUND-LEVEL CONCENTRATIONS 3
  OTHER CONSIDERATIONS 12
  SUMMARY 15
  CONCLUSIONS 17
  REFERENCES 19

ANNOTATED BIBLIOGRAPHY 21
  TALL STACKS 23
  ATMOSPHERIC PHENOMENA 39
  MISCELLANEOUS 79
  ADDENDUM 99

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National Air Pollution Control Administration Publication No. APTD 69-12

TALL STACKS, VARIOUS ATMOSPHERIC PHENOMENA, AND RELATED ASPECTS

DISPERSION FROM TALL STACKS: A DISCUSSION

INTRODUCTION

This document is a compilation of abstracts and references to recent articles dealing with tall stacks, various atmospheric phenomena, and related subjects.* Atmospheric dispersion from tall stacks, particularly as it relates to ground-level concentrations of SO_2, is discussed.

This discussion is based on selected references and is not presented as an all inclusive treatment. No attempt has been made to discuss every condition associated with tall stacks, neither has an effort been made to provide a complete state-of-the-art on this subject.

References and abstracts appearing in the annotated bibliography were obtained from several literature sources, and are arranged alphabetically under three topics, according to first author or first significant word in the title when no author is given.

Referenced materials that were generated by the National Air Pollution Control Administration and other Public Health Service agencies are available from the Air Pollution Technical Information Center. The appropriate Air Pollution Technical Information Center accession numbers are provided in the bibliographical entries.

STATEMENT OF THE PROBLEM

Under any given set of meteorological conditions, the ground-level concentrations of a gaseous pollutant emitted at a constant rate into the atmosphere will become smaller as the effective height of emission of the pollutant into the air is increased. This is a truism. A fixed rate of emission at a fixed height does not uniquely determine the resultant ground-level concentrations, nor is it a certainty that sensibly significant concentrations at the ground will always result from even large emission rates from elevated sources. The magnitude of ground-level concentrations and their temporal and spatial variation depend upon the (non-linear) interactions of an impressive number of factors, among which the major ones are:

1. Strength of the source (e.g., emission rate in grams per second).

*This document is a revised edition of "Tall Stacks, Various Atmospheric Phenomena and Related Aspects" dated August 1, 1968, U.S. Department of Health, Education, and Welfare, Public Health Service, Arlington, Virginia 22203.

2. Physical height of the stack or chimney.
3. Topography of the region surrounding the stack.
4. Geometric relationships between the stack and the building complex upon (or near) which it is located.
5. The rate of transformation or decay (if any) of the pollutant.
6. The temperature and efflux velocity of the material at the time of release.
7. The temperature and stability structure of the atmosphere through the depth in which the "plume" is dispersing, and their variations in time and space.
8. The wind velocity and its variation in time and three-dimensional space through the dispersing layer.
9. The intensity and spectral distribution of atmospheric turbulence in space and time through the dispersing layer.
10. The "effective" stack height, i.e., the sum of the physical stack height and the plume rise due to inertial and/or buoyancy forces. (Note: there is no universally accepted definition of conditions that mark when or where the effective height of a plume has been reached.)

Not all of these factors are independent; e.g., number 10 can be a function of all of the others, and 9 strongly depends on 7 and 8, and possibly 3 as well. For existing installations, only factors 1 and 6 may be controlled or modified by the operators. Factors 2, 3, and 4, which bear on aerodynamic effects that might bring elements of the plume prematurely to the ground, are fixed. Factor 5 is a property of each pollutant and varies with environmental factors, such as air temperature, humidity, and sunshine. The meteorological phenomena, 7, 8, and 9, may be highly variable in all space dimensions and in time, although some degree of diurnal and seasonal regularity is usually discernable.

Given this heterogeneous array of fixed, quasi-controllable, and quasi-random functions, the central problem for air pollution meteorologists is to derive and validate the quantitative relationships of these functions to resultant ground-level concentrations over various time periods of interest. That is, as a basis for evaluating a given stack, the meteorologist must derive a diffusion climatology that will establish the occurrence frequency of a range of meteorological conditions and provide estimates of the ground-level concentrations that will occur within a given atmospheric condition.

It is not the purpose of this report to review all of the significant aspects of atmospheric dispersion; this has already been done in available literature, e.g., references 1 and 2, and summarized in handbooks, references 3 and 4. Attention here is limited to particular consequences of the continuous release of large quantities of pollutants (particularly SO_2 and fine particulates) from "tall" stacks (over 150 meters or 500 feet).

GROUND-LEVEL CONCENTRATIONS

Theoretical Considerations

No general complete theory has been formulated to express the physical relationships between ambient concentrations of air pollutants and the relevant causative factors and processes. Partial or semitheoretical expressions have been derived for limited classes of simplified conditions and situations. These have been based on analogy to heat flow in fluid materials, or on the statistical theory of turbulence, which deals with averaged properties of fluid motions. Although recent extension of these theories to motion in stratified media appears promising, the numerical evaluation of critical parameters, such as exchange or diffusion coefficients for the complete range of atmospheric stability conditions, must be based on experiment. As a result, a large body of empirical data has been accumulated over the past several decades from activities connected with Chemical-Biological-Radiological warfare, atomic energy, and air pollution research. Working equations, including appropriate values of the diffusion parameters, have been derived from these field studies and have proved useful in the solution of practical air pollution problems arising from both ground-level and elevated sources. However, because most of the studies of continuous emissions involved stacks shorter than 300 feet, and because observations at upper levels are technically difficult, few of the data obtained relate directly to plume dispersion from taller stacks.

This dificiency has not precluded the estimation of ground-level concentrations to be expected from tall stacks. In such estimates, however, the values of height-dependent atmospheric variables (diffusion coefficients) used in the working formulae, are largely speculative extrapolations, subject to validation by relevant field observations and experiments. Further, recent ground-level sampling at distances 5 to 20 miles from the base of tall stacks demonstrates that earlier conclusions, based on close-in sampling (up to 5 miles), can significantly underestimate the magnitude of ground-level concentrations possible at greater distances. The importance of the actual relevancy of data collected to validate aspects of tall stack effluent dispersion cannot, therefore, be overemphasized.

Figure 1 shows a convenient and often referenced scheme for classifying the dispersion behavior of stack gases on the basis of ambient atmospheric stability conditions in the lower atmosphere.[2] Theoretical calculations of pollutant concentrations in time and space are normally set, explicitly or implicitly, within the framework of such a classification. Although that practice is also followed in the calculations of ground-level concentrations from tall stacks presented in Tables 1 and 2, the analogies are only approximately correct. The illustrations in Figure 1 refer to conditions in the lower 1000 feet of the atmosphere, but effluents from tall stacks often have effective heights in the range of 1000 to 3000 feet above ground because of plume rise due to buoyancy and inertial effects. The diurnal variation of stability conditions is a function of height and season of the year, and is generally not so marked above 1000 feet. Turbulence is not as intense and variable at such heights as it is nearer the ground.[5] The over-all consequences, in qualitative terms, are that the magnitude and frequency of processes that bring plume effluents to ground level are reduced.

Table 1 presents two sets of hypothetical calculations of ground-level concentrations of SO_2, for various effective stack heights as a function of distance, under typical daytime conditions. One set was presented by M. E. Smith in a recent paper,[6] and the other was computed by the Meteorology Program, National Air Pollution Control Administration.

The meteorological situation represented in this table is most nearly characterized as Condition A of Figure 1. On an annual basis, this is one of the most frequent situations experienced in the United States. It has a frequency of about 30 percent. Note that the NAPCA estimates of maximum concentrations are lower but at greater distances from the source. This is probably attributable to NAPCA investigators assuming somewhat different dispersion rates at the higher elevations from those used by Smith. This issue can be resolved only by properly designed experiments. From a practical point of view, however, for effective stack heights

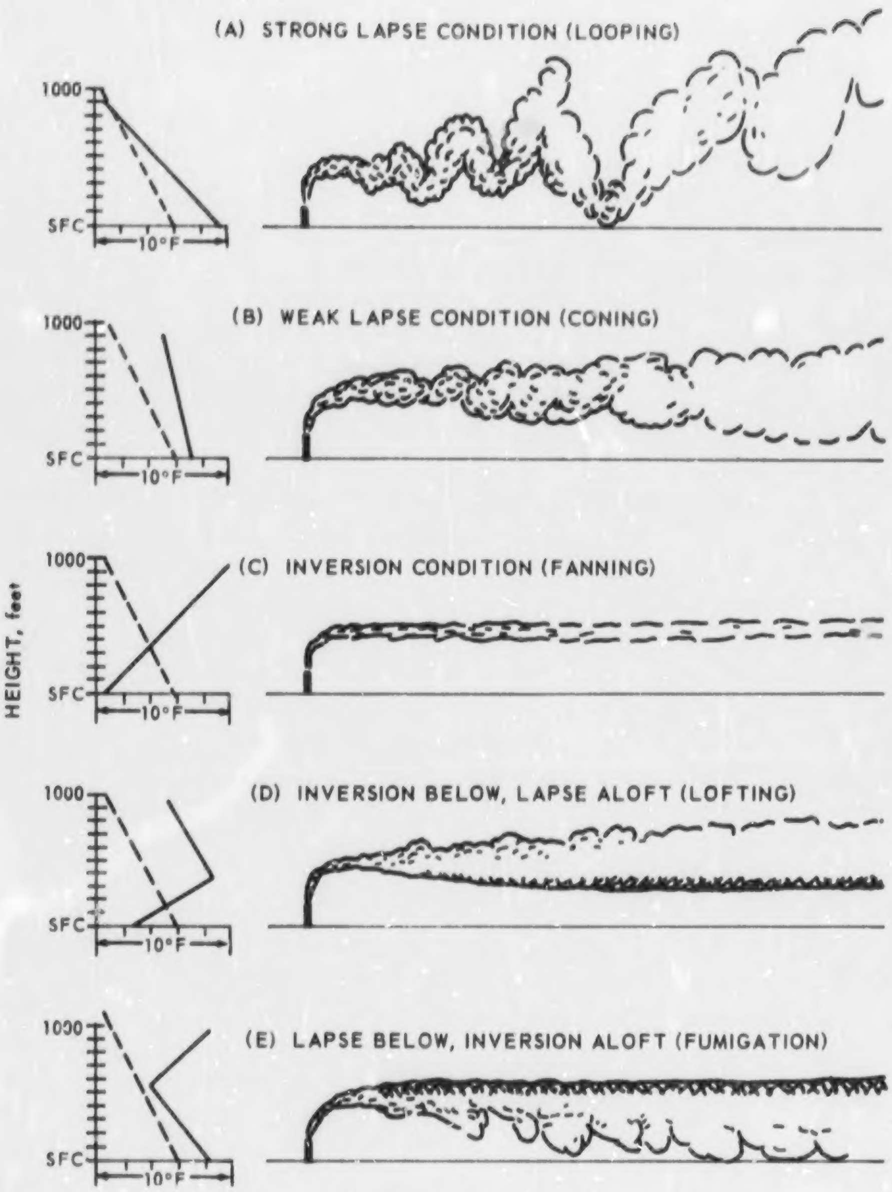
Table 1. HYPOTHETICAL GROUND-LEVEL CONCENTRATIONS OF SO_2 FROM VARIOUS EFFECTIVE STACK HEIGHTS UNDER TYPICAL DAYTIME CONDITIONS[a]

Effective stack height, m	Author	Distance of maximum, km	Downwind concentrations, ppm				
			Maximum	1 km	5 km	10 km	50 km
1000	Smith	7.6	0.03	0	0.03	0.03	0.004
	NAPCA	14.7	0.02	0	0.001	0.002	0.005
500	Smith	3.4	0.14	0.01	0.12	0.05	0.004
	NAPCA	6.9	0.08	0.00	0.02	0.05	0.005
100	Smith	0.6	3.36	2.20	0.19	0.06	0.004
	NAPCA	1.2	1.85	1.15	0.44	0.14	0.005

[a] Following Smith, assumed SO_2 emission rate of $8 \times 10^5 cm^3 sec^{-1}$ "typical of a 600 Mw - 2 percent S plant", and mean wind speed of 6 m/sec.

Table 2. HYPOTHETICAL MAXIMUM GROUND-LEVEL CONCENTRATION OF SO_2 FROM VARIOUS EFFECTIVE STACK HEIGHTS UNDER WEAK LAPSE CONDITIONS

Effective stack height, m	Distance of maximum, km	Maximum concentration, ppm
1000	42.7	0.01
500	18.2	0.05
100	2.5	1.36



(A) STRONG LAPSE CONDITION (LOOPING)

(B) WEAK LAPSE CONDITION (CONING)

(C) INVERSION CONDITION (FANNING)

(D) INVERSION BELOW, LAPSE ALOFT (LOFTING)

(E) LAPSE BELOW, INVERSION ALOFT (FUMIGATION)

DASHED LINE REPRESENTS ADIABATIC RATE

Figure 1. Schematic representation of stack gas behavior under various conditions of vertical stability.

above 100 meters, differences in the computed maximum concentrations are only slightly significant. More important, perhaps, is the distance from the stack one must look to find the highest concentrations.

Table 2 presents calculations made by the Meteorology Program, National Air Pollution Control Administration of ground-level SO_2 concentrations under conditions similar to those depicted in Part B of Figure 1. Data in Table 2 is calculated on the basis of the same conditions of SO_2 emission as those assumed for Table 1. Although Condition B (coning) occurs much less frequently than Condition A (prevailing 5 to 10 percent of the time), it is another situation in which pollutants emitted aloft are brought to the ground. Although at somewhat lower concentrations than those given in Table 1, the pollution from a coning plume will affect a given point for a longer period of time. Plume coning is usually associated with moderate to high winds and overcast skies.

Condition E, inversion break, is a potentially critical situation. As noted by Moore,[7] "when one is concerned with the rise and dispersion of the effluent from a tall stack, the occurrence of stable conditions above the top of the stack may have a very different effect from the presence of a stable layer below the stack."

If the potential temperature increases with height above the source emission point, the air is stable and vertical turbulence and mixing are strongly suppressed. Horizontal mixing processes are still active but somewhat less so than those that produce the coning effect. Inhibited vertical motion together with limited horizontal motion leads to the formation of a relatively thin plume, called "fanning" (Condition C, Figure 1). During the day, when solar heating establishes the mixing layer, thermal turbulence can reach the plume environment, permitting dispersion of plume effluent to the ground along its length. For a brief period, usually 30 to 60 minutes, high concentrations are brought to the ground. This fumigation was fully studied by Hewson in 1944, during the Trail, British Columbia, investigation.[8]

Fumigation can occur almost daily from a plume emitted from a short stack, as exemplified in Figure 2. In this case the effective plume height was approximately 800 feet above ground level. It is clearly evident that the plume effluent was brought to the ground for a considerable distance downwind. While the plume effluent is contained by the stable layer, it will remain aloft; however, over most of the nation during all seasons of the year the daily maximum mixing depth is deep enough to envelop the layer in which the plume from even the tallest stacks is embedded.[9, 10] The resultant ground-level concentrations are a function of source strength, plume height, horizontal spread, and wind speed at plume height.

The experience at Trail, British Columbia, demonstrated that plumes that were high in SO_2 content and trapped in a stable layer retained their physical identity over great distances and damage to vegetation was noticed many miles from the source.[8] Recently Professor Brohult attributed forest damage in Sweden to SO_2 transported from Western Europe.[11] Of course, the damage in Sweden may not have been due to fumigation alone but, if Dr. Brohult's thesis is correct, it may have been due to frequent, low-level insult by transported SO_2. Those concerned with air quality management should note that, regardless of the height of release, the exposure to distant receptors is similar. As Smith[6] has pointed out,

> . . . stacks possess no magic power to eliminate a pollutant. They

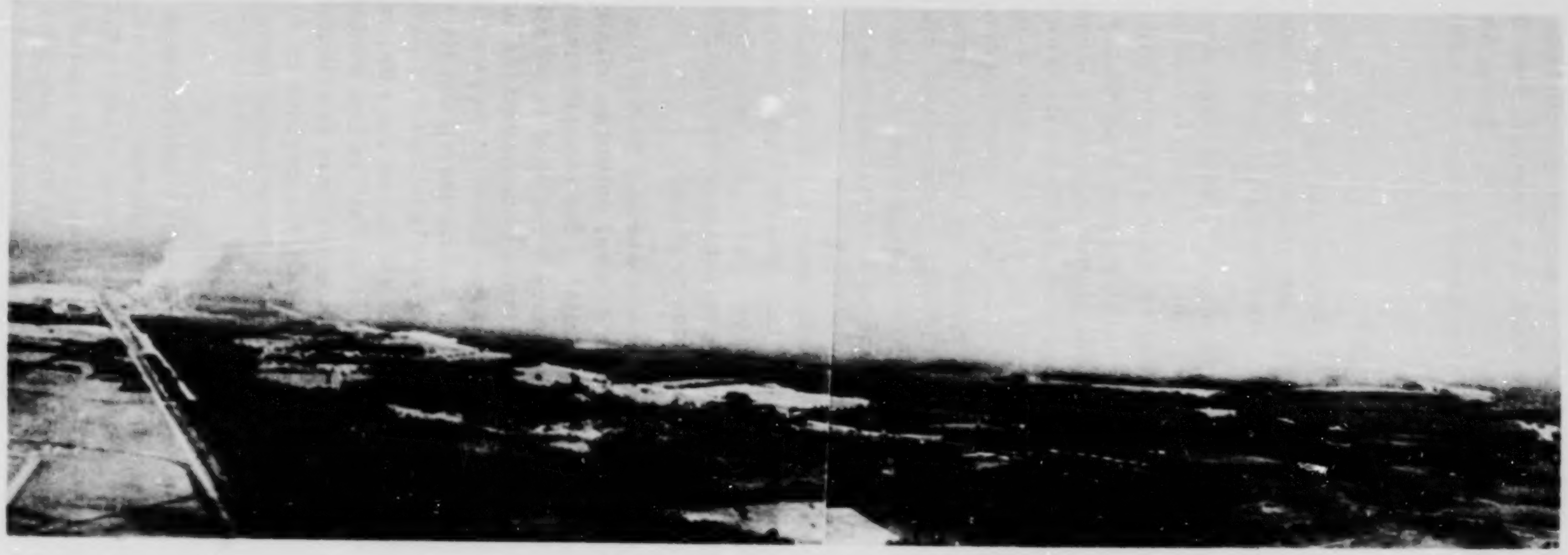


Figure 2. An illustration of a fumigating plume.

do not reduce by one gram the total amount of pollution released to the atmosphere. They distribute it in a different way than would be true of a low-level source, but a receptor at a great distance from a stack will receive substantially the same concentrations no matter what the source height.

Measured Ground-Level Concentrations

Ultimately, the controversy about whether the tall stack is an interim or complete solution in air quality management must be resolved by meaningful studies of dispersion from tall stacks. According to Gartrell[12]:

> Our experience at large modern plants to date suggests two models that need more intensive evaluation. The first involves high short-term ground-level concentrations which may occur with a high frequency. While flue gases are emitted from high stacks and have appreciable plume rise, the total plume volume is large and segments may be brought to ground level by thermals typical of moderate instability. Although long-term, say 30 minute average, concentrations are consistently low, 2- to 5-minute concentrations may be relatively high. The second model we believe might involve infrequent, but possible moderately high ground-level concentrations at considerable distances from the source over an extended period of time. This might occur where upward diffusion is limited by a subsidence inversion and strong mixing from ground-level to plume top occurs below the subsidence inversion. This would be characterized by the infrequent stable anticyclonic conditions occurring in the Eastern United States. More time, records, and observations will be necessary for confident evaluation of the significance and validity of this model for large power plants.

Most measurements to date have been made within 3 to 5 miles of a tall stack. In 1966, a rather detailed analysis of ground-level pollution within 3.5 miles of the High Marnham power station in Great Britain, the contribution to surrounding measuring sites from two 450-foot chimneys were said to be nil.[13] Unusually high measured concentrations (in one instance concentrations of more than 50 parts per hundred million were measured for 8 hours) were attributed to distant urban sources. Other authors, however, in discussing the High Marnham data, report that concentrations at one sampling site average 5.4 parts per hundred million everytime the wind blows from the station to the site, which it does about 10 percent of the time.[14] These authors state that in one winter the measuring site experienced, on seven occasions, concentrations (attributed to High Marnham) of more than 25 parts per hundred million SO_2 for periods of 28 to 60 minutes. On one occasion, a concentration of this magnitude lasted for a period of 180 minutes.

Table 3 presents ground-level observations taken between 2 and 5 miles (Station A in the valley 2.5 miles, Station B on plateau 2.25 miles, and Station C on plateau 4.9 miles), from the Clifty Creek Power Plant in Indiana.[15] The Clifty Creek chimneys extend 683 feet above plant grade and about 300 feet above the plateau northeast of the plant. An analysis of data taken for this study over a 4-year period showed no hourly mean concentrations above 1 part per million at the three SO_2 monitoring stations, although the authors stated, that it was agreed that concentrations slightly above that level may occur infrequently on the plateau north of Clifty Creek Plant, with an occasional peak just reaching the odor threshold (2 parts per million).[15] However, because of the limited sampling network it is difficult to determine how frequently concentrations of a given value occurred around the plant.

Table 3. TYPICAL SO_2 CONCENTRATIONS MEASURED NEAR CLIFTY CREEK POWER PLANT, ppm

Gustiness class[a]	Station A		Station B		Station C	
	Average	Peak	Average	Peak	Average	Peak
B_2	0.10	0.40	0.10	0.25	0.05	0.20
B_1	0.10	0.40	0.07	0.30	0.10	0.25
C	0.05	0.20	0.10	0.40	0.10	0.40

[a] Brookhaven gustiness classification.[16]

Table 4 presents ground-level observations of 30-minute average SO_2 concentrations taken with four autometers by the Tennessee Valley Authority at the Bull Run Plant near Knoxville, Tennessee. The instruments are sited at the given distances along a line approximately northeast of the 950-megawatt plant, which has a single 800-foot stack. The data presented are selected maximum 30-minute average SO_2 registrations, which occurred at the four sites. Winds along the line of samplers occurred 13.6 percent of the time during the 18-month period.

Table 4. NUMBER OF REGISTRATIONS OF 30-MINUTE AVERAGE SO_2 CONCENTRATIONS NEAR BULL RUN PLANT, ppm

Distance, miles	Concentration, ppm								
	0.34	0.26	0.24	0.22	0.20	0.18	0.16	0.14	Total
2.6	1		2	2	1		5		12
4.9		1	1		3	7			12
6.9	1		1	3	5				10
9.7						1		5	6

A study by TVA revealed that 85 percent of the data in Table 4 were recorded on 16 separate days. The study showed that the 16 days were associated with a given set of meterological conditions, summarized by TVA as follows:

> Meteorological conditions during maximum 30-minute average SO_2 concentrations at the Bull Run Steam Plant during January 1966-June 1967 are remarkably similar and may be identified with one basic or atmospheric model. The lower atmosphere was under the influence of weak anticyclonic circulation with stable air throughout

> the first few thousand feet from late afternoon through late morning. Average wind speed generally varied between 8 and 15 miles per hour and was adequate to contain the plume within this stable layer. Skies were mostly clear, under anticyclonic circulation, and solar insolation was sufficient to develop thermally induced atmospheric mixing from surface through the plume environment by late morning or early afternoon. This temperature transition (or stability change) resulted in initial SO_2 registrations appearing at most autometers about 11:30 a.m. to 12:30 p.m. reaching maximum concentrations 1 to 2 hours later when the mixing had penetrated through most of the plume environment, and then decreasing to zero by 4:30 to 6:30 p.m. with the onset of stable conditions in the near-surface layers.[17]

On the basis of TVA experience, one may conclude that significant surface concentrations are attributable to emissions from tall stacks in the presence of light winds and limited mixing layers. Futhermore, preliminary data from another current investigation by the Tennessee Valley Authority, with the support of the National Air Pollution Control Administration, show that inversion-breakup fumigation also occurs with tall stacks; however, these fumigations are infrequent because surface-based radiation inversions are rarely deep enough to entrap the plume.

Table 5 lists some of the peak and average SO_2 concentrations measured near the Paradise TVA power plant at ground level on days when a temperature inversion existed in the lower atmosphere. The surface-based temperature inversion extended to or above the stack top (600 feet) on 5 of the 7 days on which experiments were conducted between September 9 and 13, and between October 10 and 21, 1966. On four of these days radiation inversion extended up through the plume. The peak concentration of 0.64 part per million occurred when the Paradise plume, which had been trapped at 1300 feet above ground level within an inversion layer, was brought to the ground.

Table 5. PEAK AND AVERAGE SO_2 CONCENTRATIONS MEASURED AT GROUND LEVEL NEAR PARADISE PLANT

Distance at point of maximum concentration, miles	SO_2 concentrations, ppm				Total time SO_2 in area, minutes
	Peak	Average	Average	Average SO_2 for duration	
8	0.21			0.13	20
9	0.64	0.60	0.52	0.42	95
9	0.41	0.34	0.27	0.27	60
6	0.22	0.15		0.14	55
10	0.23	0.22		0.21	53
7	0.24	0.21	0.18	0.18	60
7	0.30	0.18		0.15	45

The distance at which the point of maximum concentration occurred was in the range of 6 to 10 miles from the 600-foot stacks of the Paradise plant. The highest peak concentration, 0.64 part per million, was measured 9 miles from the source.

Initial measurements by the NAPCA taken in Western Pennsylvania (Large Power Plant Effluent Study) have indicated peak SO_2 concentrations from the 800-foot chimney being studied of up to 1.4 part per million at ground level. Peak concentrations above 0.2 part per million occurred as far as 11 miles from the plant, which was generating approximately 900 megawatts at the time (half of its planned capacity).

Figure 3 summarizes available data from preliminary reports on some of the tall stacks discussed above. This figure shows that the 30-minute average concentrations are in the range of 0.2 to 0.6 part per million. Although these 30-minute mean concentrations from tall stacks are of about the same order of magnitude as concentrations from smaller stacks, it is significant that the distances at which they occur are more than 4 kilometers (2.5 miles) from the source, the majority occurring 8 to 16 kilometers (5-10 miles) away. The 1967 High Marnham data[18] are presented in Figure 3 to illustrate the comparability of measured concentrations at greater distances from stacks with a range of height differences. The High Marnham stacks are about half the height of the others.

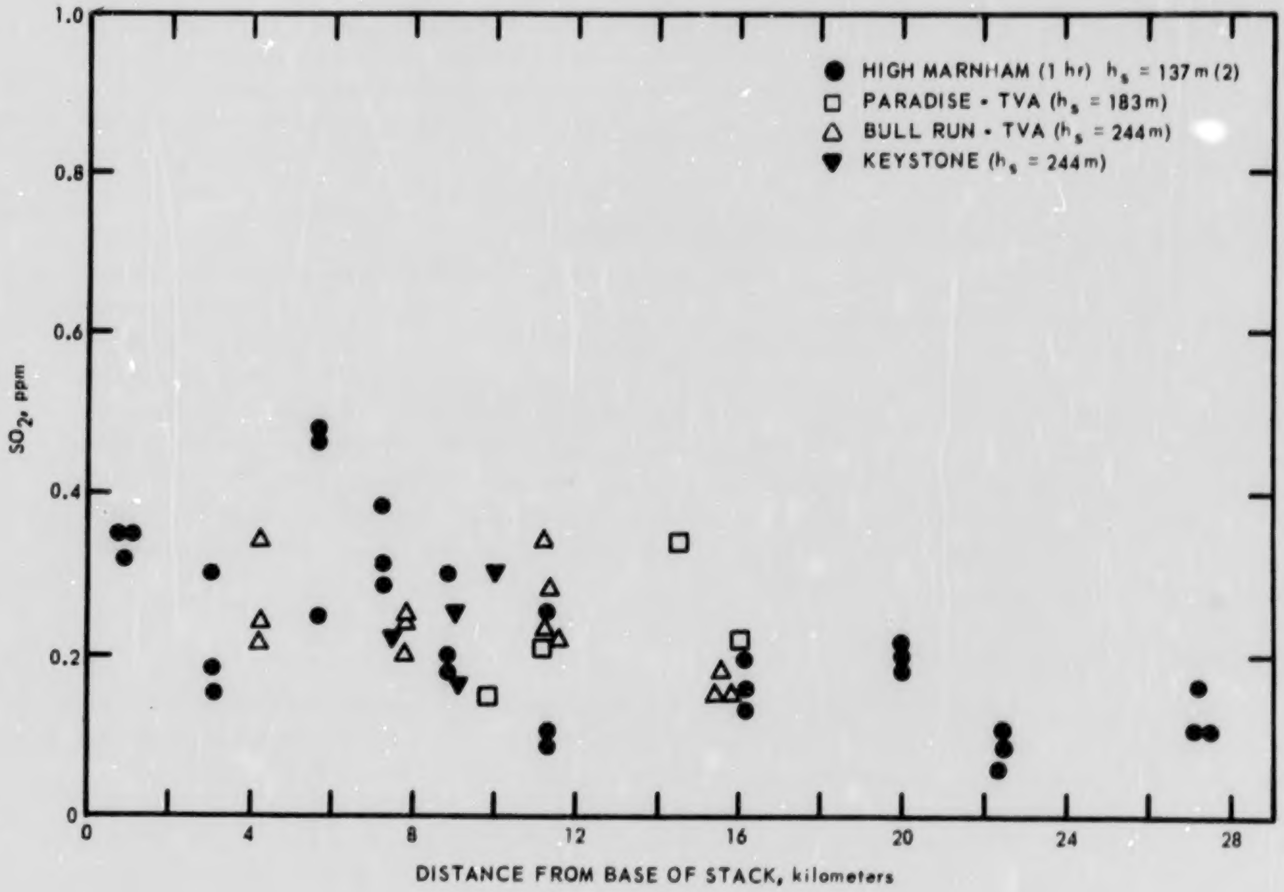


Figure 3. Maximum observed ½-hr SO_2 at ground level from power plants >500 Mw.

OTHER CONSIDERATIONS

Plume Rise

The height to which a buoyant plume rises is one of the primary factors controlling ground-level concentrations of pollution downwind of an industrial source. Obviously, the higher a plume rises in the atmosphere, the greater the volume of air available for dilution of the atmospheric contaminants before they are dispersed to ground level.

The rise of a plume after it leaves a stack is due to its buoyancy and momentum. These elements depend on the physical characteristics and emission factors of the particular stack and also on the prevailing meteorological conditions. Stack factors affecting plume rise are exit velocity and temperature of the stack gas, and inside stack diameter. Meteorological elements determining plume rise are wind speed, air temperature, atmospheric stability, turbulence, and wind shear.

Although a number of plume rise equations have been developed over the years, experts in atmospheric dispersion have not been able to agree on a given equation to calculate plume rise under all circumstances. In general the semi-empirical plume rise formulae have been developed from data on relatively small sources and consequently may lead to significant errors in stack height estimates when they are applied to the larger industrial sources of today.

Realizing the growing need for reliable and comprehensive plume-rise data, the Tennessee Valley Authority initiated a special 3-year research project entitled "Full Scale Study of Plume Rise at Large Electric Generating Stations." This study was carried out with support of NAPCA. A comprehensive report on the findings was recently published.[18]

Stack Height Versus Sulfur Dioxide Emission Rate

It was pointed out earlier that the ground-level concentration is dependent upon the effective stack height and the source emission rate. In today's literature, considerable attention is directed toward the effect of increasing stack heights, but there is little or no attention to the fact that emission rates per unit have also increased relative to those of the lower stacks.[15, 19] Figure 4 shows a comparison of physical stack height with approximate emission rates and rated capability. The figure shows that, whereas stack heights have increased by a factor of about 4, emission rates have increased by a factor of approximately 6. Thus, a good share of the benefits of increased stack heights are offset by the release of more contaminants from the stack.

Washout By Precipitation

Proponents of the idea that a stack is the most economical solution for control of large discrete sources of pollution should not overlook the problem of atmospheric scavenging, in particular washout by precipitation. Both field and laboratory investigations show that sulfur dioxide can be oxidized to sulfuric acid or an acid salt in the atmosphere, and that precipitation scavenging is the primary cleansing mechanism for airborne gases and fine particles. Since SO_2 is highly soluble in water, the washout process for this gas is absorption of the gas by drops of rain as they fall through the plume.

Recently, at a seminar arranged by the Ecological Research Committee of Sweden, Dr. Svante Oden of the Agricultural College of Uppsala, Sweden, presented his compilations of data from the atmospheric chemical network stations on the acidity and sulfur contents of precipitation over Europe and their consequences to soils, surface waters, and biological systems in Sweden. He indicated that in 1958, pH values below 5 were found only in limited areas over the Netherlands. These values are now found in an area that spreads over Central Europe, and the pH values of the Netherlands are now below 4. Dr. Oden pointed out that the acid zones are spreading, and in 1966 the isoline for pH 4.5 had extended to central Sweden. (The pH of pure water is 7; the pH of vinegar, 3.1). Information pertaining to quantitative estimates of washout by use of diffusion equation and scavenging coefficients is given by Chamberlain[20] and Engelman et al.[21]

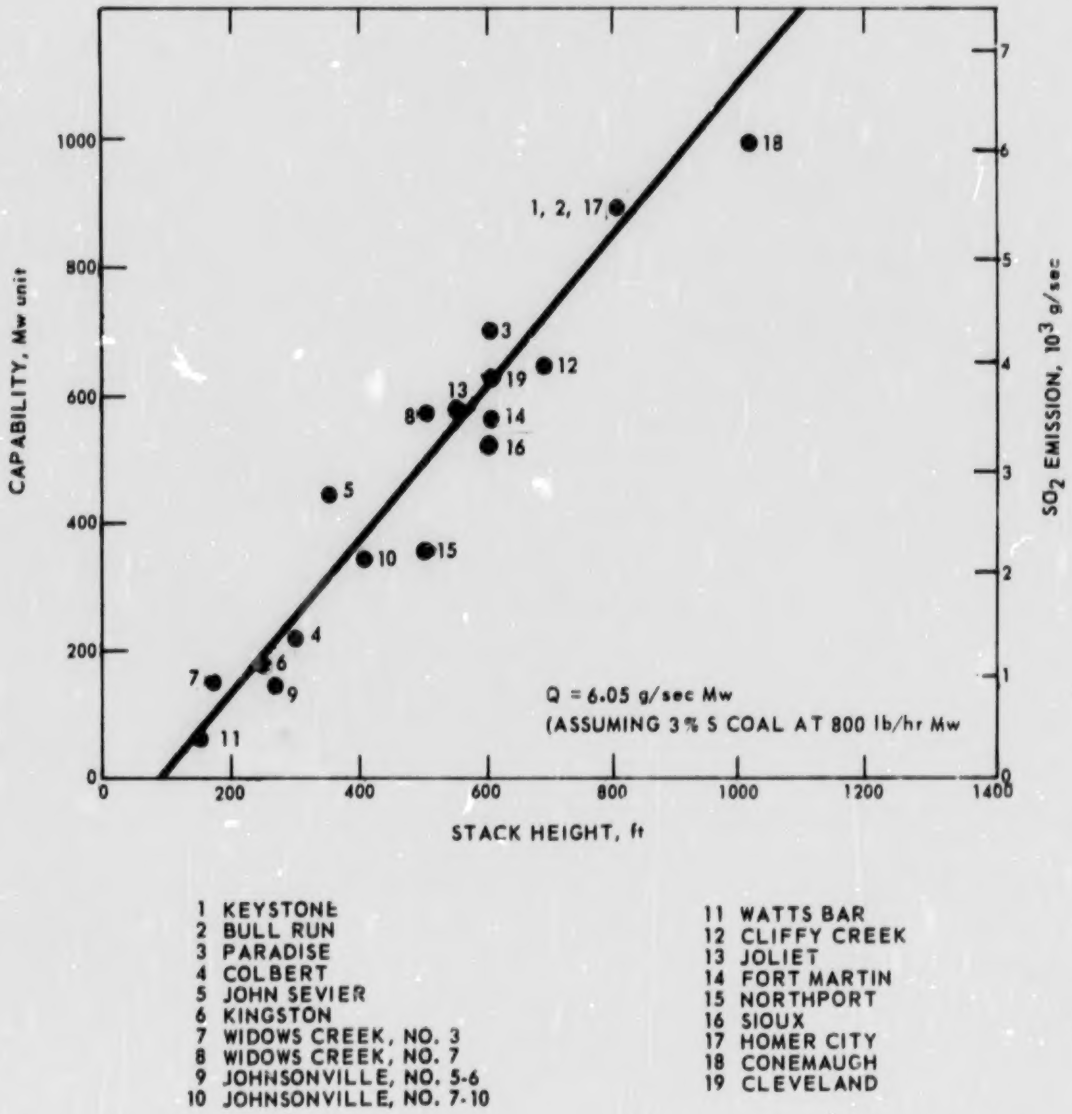


Figure 4. Sulfur dioxide emission versus stack height.

SUMMARY

Although the usefulness of tall stacks in reducing gaseous pollution in the vicinity of a plant is granted, a tall stack alone does not reduce in any manner the total pollution added to the atmosphere. Other means must be found to prevent overburdening the atmosphere with pollution, particularly under certain meteorological conditions.

The data presented in this paper show that the tall stack does not prevent all of the emissions from reaching the ground. Under a variety of meteorological conditions, including precipitation, pollution from tall stacks may result in significant concentrations at ground level.

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CONCLUSIONS

For a quantitative evaluation of the use of tall stacks in the management of air pollution it will be necessary to make meteorological measurements and air quality determinations over height and distance scales beyond those previously used in most studies.

Field observations and experiments should encompass a variety of meteorological conditions to take into account steady-state as well as transitional atmospheric regimes. It will be necessary to determine the occurrence frequency of various atmospheric regimes; particularly regimes with a low frequency of occurrence, say 1 to 5 percent of the time, since these may be the ones of most concern.

Finally, additional data are needed on the levels of pollution reaching the ground at various distances from tall stacks and on the frequency of occurrence of the higher concentrations.

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TALL STACKS

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   TALL STACKS, A POTENT WEAPON IN THE FIGHT AGAINST AIR POLLUTION.
   Power, 111(11):94-96, Dec. 1967

   Tall stacks for public utilities and industrial plants are effective remedy against gaseous pollution; while they do not prevent pollutants from reaching atmosphere, their diffusing action is such that they reduce contamination at ground level to degree acceptable to public as well as to most governing bodies; for example, chimney can be sized so as to limit ground concentration of sulfur-oxides at ground level, anywhere around plant, to around one-tenth part per million, which is satisfactory to everyone. APTIC #9699

2. Brennan, N. E.
   CONTROL OF SULPHUR DIOXIDE EMISSION FOR PROPOSED 400 MW GENERATING UNIT AT SEWARD GENERATING STATION, PENNYSLVANIA ELECTRIC COMPANY. Jackson & Moreland, Inc., Boston, Mass., Nov. 1961, 19p.

   The most satisfactory method of controlling the future ground level concentration of SO_2 emitted from the chimney of a proposed 400 mw generating unit, located on the Conemaugh River at Seward, Pennsylvania was studied. Three methods of control were investigated: (1) A 99.7% efficient precipitator and a 900 foot chimney was the basis for comparison, both as regards expense and SO_2 ground level concentration. (2) Use of washed coal with a 99.3% efficient precipitator and a chimney 500 feet high. (3) Flue gas washing equipment, installed with a 99.7% efficient precipitator and a 500 foot chimney. Minimum chimney height for the coal washing and gas washing control methods was based on a re-occurring night-time stagnation layer, reported to be under 700 ft. which effectively seals the valley and prevents dispersal of SO_2. A 500 ft. chimney should be the safe minimum height, being able to jet the plume through the layer and out of the valley. Results of the study indicated that neither coal washing nor gas washing equipment could be included in plans for a 400 mw unit. Coal washing is a technically possible, but very expensive method of controlling the ground level concentration of SO_2, when compared to the cost of a tall stack and high efficiency precipitator. The objective was to produce similar ground level concentrations by balancing a high efficiency precipitator and a tall stack against a coal washing plant combined with a shorter stack and a less efficient precipitator. Because of topographical and meteorological considerations, the minimum stack height, based on SO_2 concentrations, required with the coal washing plant had to be increased by about 100 feet to 500 feet, and to maintain the original purpose of the report the Base Plan chimney height had to be increased from 700 feet to 900 feet. The resulting reduced ground level concentrations are presented. At the

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present time, progress in flue gas washing is such that it is not possible to recommend any proven process. The non-regenerative limestone process, which is similar to the Battersea process except that the effluent is treated, is considered in this report. At best, flue gas washing must be considered to be still in the experimental stage, and to date, attempts at flue gas washing have been largely unsuccessful. APTIC #5198.

3. CONSOLIDATED EDISON COMPANY OF NEW YORK PLANS WORLD-RECORD 1000-MW UNIT FOR ITS RAVENSWOOD GENERATING STATION. Power, 107(6):53-56, June 1963.

   A proposed power plant to be located in Ravenswood, N.Y., is described in detail. The plant is 1000 MW, oil-, coal-, or natural gas-fired. Specifics on the boilers, turbines, combustion control systems, and condensate systems are presented. APTIC #9482.

4. Corey, R. C.
   AIR POLLUTION RESEARCH IN RELATION TO COAL'S FUTURE IN THE ELECTRIC ENERGY MARKET. Combustion, 39(10):21-29, April, 1968 (Presented at the 75th Anniversary Meeting, Illinois Mining Institute, Oct. 1967.

   The role of the Bureau of Mines in the air pollution field is that of an agency concerned with the most effective utilization of natural resources. A projection of the energy requirements of the nation indicates that coal will continue to be an important factor in the rapidly growing electric market. Six important possibilities for reducing sulfur emissions from coal fired electric utility systems include: unconventional electric power cycles; remotely located mine-mouth power plants; tall stacks; desulfurization before combustion. APTIC #9996.

5. Csanady, G. T.
   DEPOSITION OF DUST PARTICLES FROM INDUSTRIAL STACKS. Australian J. Appl. Sci., 9(1):1-8, 1958.

   Sutton's (1953) continuous point-source equations have been extended by Csanady (1955, 1957) to the study of dust of uniform free-falling speed, discharged from a tall stack into a horizontal wind. This theory is now applied to industrial dust with continuous particle-size distribution. To facilitate appreciation of the results, some new concepts are introduced and the characteristic features of instantaneous fall of dust are discussed. Averaging deposition rates for wind speed and direction is then considered and it is shown how the weather data generally available can be utilized. APTIC #5355.

6. DISCUSSION ON "AIR POLLUTION BY SULPHUR DIOXIDE". Part 1: The Effect of Land Configuration on Pollution by Sulphur Gases. Part 2: Sulphur Dioxide Concentrations Downwind of Tall Chimneys. Part 3: The Effect of Increased Chimney Height on Ground Level Concentrations of Sulphur Dioxide. Before the Institute, in London, 24th November 1965. J. Inst. Fuel, 39(305):256-263, June 1966.

D. H. Lucas emphasized the importance of comparing averages only on an equal duration basis. Dr. A. Parker said that the lack of information about the occurrence of temperature inversions was a drawback and that the land/sea boundary must have had an effect at East Yelland. C. Bosanquet stated that little information was given that would enable prediction of ground-level concentrations. Dr. G. Nonhebel thanked the authors for taking the advice to recalculate the ground-level concentration using the 1957 Bosanquet formula for plume rise. Dr. S. R. Craxford asked if allowances had been made for the effect of wind speed on lead dioxide gauges. Prof. R. S. Scorer criticized the lack of an experienced meteorologist on the team. Dr. D. J. Moore advised that the efflux velocity and wind speed modify the 2 1/2 times rule. D. M. C. Thomas presented some relevant calculations. Mrs. M. L. Weatherley wondered if anyone thought of applying Davidson's work, relating to valleys. C. F. Barrett contended that dilution factors were deluding. D. H. Labdon suggested apportioning the g.l.c. to the separate plumes. The authors replied to all of these discussions. APTIC #3251.

7. Flood, L. P.
AIR POLLUTION FROM INCINERATORS--CAUSES AND CURES. Civil Eng., 44-48, Dec. 1965.

Of all things that civil engineers build, probably large central incinerators cause the greatest amount of air pollution. Most large cities must resort to incineration to reduce the weight and volume of their wastes to manageable proportions, and to change the character of these wastes so that disposal does not cause secondary problems of water pollution, vermin infestation or odor emission. To attain this goal, incineration must be so complete that the organic matter left in the residue is less than 5 percent of the residue by weight. If an incinerator is to successfully burn the rated capacity of solid waste to an non-putrescible residue, without creating a nuisance, certain design principles should be followed. It is essential to recognize that: (1) The three T's of combustion must be provided: temperature for complete burnout, turbulence for thorough mixing of the combustibles with the air, and time so that combustion can be completed in the furnace. (2) Air must be used efficiently. (3) The fuel should be gently agitated to promote complete burnout without increasing fly-ash emission. (4) The most effective dust cleaning equipment should be utilized so that dust emission will be minimized. (5) A high stack is an effective means of decreasing the amount of pollution at ground level. (6) A continuous type of incinerator is likely to cause less pollution than a batch type. (7) A water-cooled furnace permits higher burning temperatures and avoids many of the costs and troubles experienced with a refractory-lined furnace. (8) Three-shift operation avoids the pollution and deterioration of plants concomitant with repeated starts and stops. (9) Not all the air pollution from an incinerator comes from the stack. Means for minimizing pollution from all sources must be provided. APTIC #0183.

8. Frankenberg, T. T.
TRENDS IN AIR POLLUTION LEGISLATION AND IN PRECIPITATOR DEVELOPMENT. Preprint, American Electric Power Service, Corp., New York, N. Y.

(Presented at a meeting of the Southeastern Electric Exchange, Miami Beach, Fla., Oct. 22, 1965.)

Public sentiment, local and state laws, and finally the entrance of the Federal government into control and enforcement make it certain that air pollution will demand more attention from design engineers and plant operators in the electric utility industry. The trend is toward much stricter limits on particulate emission, and these become even more stringent for very large fuel users. Most of the new limits are set in terms of pounds of emission per million Btu of fuel input. While restrictions are five times more stringent than fifteen years ago, developments in precipitators have moved at a more leisurely pace. Some significant improvements in electrical equipment have been made. It is suggested that an equal improvement can be achieved by closer attention to the purchasing of electrostatic precipitators, and by testing them to determine that the required conditions are actually met. Gaseous pollution should never be forgotten when discussing the role of particulate emission and its control. High stacks can be useful in both area, and codes should be written to take proper cognizance of the fact. APTIC #6615.

9. Frankenberg, T. T. 1968. HIGH STACKS FOR THE DIFFUSION OF SULPHUR DIOXIDE AND OTHER GASES EMITTED BY ELECTRIC POWER PLANTS. Amer. Ind. Hyg. Assoc. J., 29(2):181-185, Mar.-April. APTIC #10284

Experience with the satisfactory dispersion of hot gases from two power plants each larger than 1000 MW designed in 1952-1953 is detailed. The effects of this experience on the design of 825-foot stacks for the Cardinal Plant is covered, with a description of test work underway to verify the results. This includes dustfall and sulfur dioxide sampling at fixed locations. A case is made for the use of high stacks to control ground level concentrations, rather than resorting to fuel restrictions or emission standards which are unnecessary and economically unsound.

10. Gartrell, F. E.
CONTROL OF AIR POLLUTION FROM LARGE THERMAL POWER STATIONS. Rev. Soc. Roy. Belge Ingrs. Ind. (Brussels), No. 11, pp. 471-482, Nov. 1966.

Measures for the removal of particulates from stack gases and reductions in SO_2 emissions as well as the dispersion of emissions by high stacks and control by operational procedure are discussed. The results of air pollution monitoring near large power stations of the TVA are reviewed. Gas cleaning devices have been perfected so that 99.5% of the original ash content of the coal may be removed, although costs increase rapidly above 95%. In the future, removal of 99.5% of ash may be necessary in some plants based on combined mechanical and electrostatic collectors. There is a trend toward using electrostatic precipitators alone because of the high draft losses with mechanical collectors. While there are a number of promising developments in the removal of SO_2 from fossil fuels, the principal reliance for the next few years will have to be placed on dispersion from high stacks with possible supplementary operational controls. The height of TVA stacks varies from 150 to 800 ft., and tables are given of relationship between the maximum ground level SO_2 concentration, stack height, and wind speed. Data are also given of the frequency of occurrence of various ground levels of SO_2 in the area around the plants. APTIC #4200.

11. Gartrell, F. E.
STATEMENT TO HOUSE SUBCOMMITTEE ON SCIENCE, RESEARCH AND DEVELOPMENT. TVA, Norris, Division of Health and Safety, 15p., 1966.

A review of TVA experience in air pollution control, more specifically from large coal-fired power plants, is presented. The principal elements of the TVA study program are (1) monitoring of SO_2 concentrations in the vicinity of each plant, (2) collection and analysis of on-site meteorological data, (3) biological studies to determine effects of plant emissions on vegetation in special experimental gardens and in surrounding areas, (4) full-scale studies of stack gas dispersion, (5) investigations of possible means for reducing emissions through modification of plant operations during periods when meteorological conditions are unfavorable for dispersion, and (6) research on processes for removal of SO_2 from stack gases. APTIC #3344.

12. Gasiorowski, K.
(ENERGY GENERATION FROM LIQUID FUELS.) ENERGIEERZEUGUNG AUS FLUESSIGEN BRENNSTOFFEN. Gesundh. Ingr., 86(4):116-122, Apr. 1965. Ger.

Air pollution due to oil-fired installations is caused by sulfur dioxide, carbon dioxide, nitrogen oxides, and products of incomplete combustion (carbon monoxide, hydrocarbons, ashes, and soot). Percentual share of these agents in flue gases produced from different fuel oils under various combustion conditions is given. Efficiency of high smoke stacks in dispersing SO_2 is discussed and presented graphically. Statistical data are presented on share of automobile engines, domestic furnaces, and industrial furnaces in cities' air pollution due to SO_2. APTIC #5477.

13. GIANT STACK WILL VENT SULFUR OXIDES ABOVE SMOG CEILING. Chem. Eng., 74(17):104, Aug. 14, 1967.

A 700 ft. smoke stack at a petroleum refinery in The Netherlands that will discharge sulfur-bearing flue gases is described. The structure will conduct the sulfurous flue gases to above the meteorological inversion layers that often form and act as a ceiling for the atmospheric layer below. APTIC #8701.

14. HEARING ON SENATE BILL S. 780 BEFORE THE SUBCOMMITTEE ON AIR AND WATER POLLUTION OF THE COMMITTEE ON PUBLIC WORKS. Nine-

teenth Congress, First Session. Op. cit., Part 4, pp. 2043-2047, 2107-2118, 2278-2285, 2287-2311, 2312-2316, 2550-2568, 2567-2589.

Various statements on the problem of air pollution and the usefulness of tall stacks to eliminate these problems were presented to the Committee.

15. Hill, G. R., M. D. Thomas, and J. N. Abersold
HIGH STACKS OVERCOME CONCENTRATIONS OF GASES. Mining Congress Journal, 31(4):21-34, April 1945.

A discussion of the measurements of sulfur dioxide taken in the farming areas surrounding certain plants and other related data is presented. Years of study and research have produced gratifying results in the problem of handling objectionable concentrations of sulfur dioxide gas. The tall stack method of dispersion has revealed some very interesting and useful phenomena. High stacks coupled with high temperatures have largely solved the sulfur dioxide problem at many smelters. In addition they have vastly improved operating conditions by added draft. The curves shown tend to corroborate the Bosanquet and Pearson formula of decrease of gas concentration proportional to the inverse square of stack height.

16. Knox, G.
INDUSTRIAL CHIMNEYS FOR OIL-FIRED PLANT. Smokeless Air, 38(143): 50-54, 1967.

The problems with flue systems and chimneys of oil-fired plants are discussed and a means of overcoming these problems is suggested. Chimney height is usually decided under the provisions of the Clean Air Act 1956 and is related to the estimated maximum emission of sulphur dioxide. The plume rise from the chimney exit gives in effect an addition to the physical height and it is nonsensical to destroy this plume by the use of a cowl. A cowl will not avoid downdraught and its value in the prevention of moisture ingress is extremely doubtful when one considers that 1 in. rainfall is equivalent to the combustion of 2 gallons of oil fuel. To ensure the adequate dispersal of gases, it is essential that a suitable gas exit velocity is maintained. Suggested minimum velocities are 20 ft. per second for plant operating in natural draught and 25 ft. per second for plant equipped with FD or ID fans. It is essential to ensure that under all load conditions, no gas side surfaces in the system drop in temperature to the acid dew point or below. Heat losses must therefore be calculated for all load conditions to determine the required insulation values for the materials used in construction. Very few modern industrial oil-fired plants rely on natural draught. Chimney height required to satisfy the Clean Air Act may create a greater draught than that required for the efficient operation of the combustion equipment and some form of draught control may be required. It is essential to ensure that such a control system does not admit large volumes of cold air into the system. It is essential that siting the chimney where it may be affected by downdraught and eddies from any adjoining buildings must be avoided. Maintenance must be carried out on the flue system in addition to the combustion equipment so that the performance of a basically good system is not ruined by lack of attention. APTIC #8107.

17. Leavitt, J. M., S. B. Carpenter and F. W. Thomas
AN INTERIM REPORT ON FULL-SCALE STUDY OF PLUME RISE AT LARGE ELECTRIC GENERATING STATIONS. Preprint. (Presented at the 58th Annual Meeting, Air Pollution Control Association, Toronto, Canada, June 20-24, 1965.)

An interim report on the current plume rise research project conducted by TVA under sponsorship of USPHS is presented. The first two years of the 3-year study were completed in spring 1964 and were devoted primarily to field data collection. The third year will be used for data analysis and final report preparation. Plume rise data were collected at six coal-fired steam-electric generating stations within the TVA system. Unit ratings ranged from 112 to 650 megawatts with stack heights varying from 170 to 600 feet. Measurement of plume profile was made by three techniques -- ground level photography, ground level modified transit readings, and helicopter observations. Meteorological measurements included wind direction and wind speed profiles by double-theodolite technique and vertical temperature profiles by helicopter. A description is given of the field instrumentation and data collection program and of a typical day's field work. Typical data, including plume photographs, wind direction and wind speed profiles, vertical temperature gradient, and computer plume profile plots, are displayed. APTIC #0691.

18. Lucas, D. H.
APPLICATION AND EVALUATION OF RESULTS OF THE TILBURY PLUME RISE AND DISPERSION EXPERIMENT. Atmospheric Environ., 1(4):421-424, July 1967.

The more important conclusions to be drawn from the papers presented for discussion at the symposium on the Tilbury plume experiment are summarized. A formula for calculating the plume rise (Z_{max})m in neutral conditions at wind speed U(m sec^{-1}) for a stack emitting heat at the given rate is presented. The expression for the maximum ground level concentration in neutral conditions averaged over 3 min from a source of strength (Q_s) is given. Adjustment factors for other atmospheric conditions and for longer sampling periods are also given. The meteorological instruments involved very little new development and performed satisfactorily. The recorders performed well but there was some variability in their calibrations. The variation in calibration from recorder to recorder can be represented by a standard deviation of about 10 percent of the value being recorded. Searchlight results are reasonable but it cannot be claimed that the results can be relied upon. The use of a laser has been successful. Considerable reliance can be placed on the validity of the deductions made from the lidar results. Plume rise can continue for a horizontal distance of 1000 m or more. With medium or strong winds plume rise is little affected by lapse rate. The thermal effects of an inversion (of potential temperature) tend to be compensated by the lack of turbulence in the inversion and the slower spread of the plume. With light winds plume rise is decreased by an inversion, but this combination of circumstances rarely leads to critical concentrations from large sources. Turbulence was found to decrease above a height of 100 m. Apart from the low wind condition, an inversion probably has a more important effect on the dispersion of the plume after it has completed its rise than on the plume rise. APTIC #8249.

19. Manier, G.
DETERMINING THE REQUIRED HEIGHT OF TWO CHIMNEYS. Staub (English Transl.), 26(3):33-42, March 1966.

A method is described for the determination of the required height of a chimney which is to be built in the vicinity of an already existing chimney. The method is explained by an example. APTIC #2693.

20. McDaniel, W. N.
COMPENSATION FOR GAS EMISSION VELOCITY IN CALCULATIONS OF STACK GAS DISPERSION. Air Repair, 3(3):188-194, Feb. 1954.

It is generally recognized that the ground-level concentration of material normally emitted from a stack is reduced if the stack height or stack gas velocity is increased. This is usually considered to mean that stack gas velocity may be substituted for stack height if the circumstances require it. A method of calculation by which the stack height equivalent of gas emission velocity may be determined is proposed. The theory of the proposed method of calculation is presented in detail, and the solution to a specific problem is given. APTIC #6092.

21. McLaughlin, J. F., Jr.
ATMOSPHERIC POLLUTION CONSIDERATIONS AFFECTING THE ULTIMATE CAPACITY OF A THERMAL-ELECTRIC POWER PLANT SITE. J. Air Pollution Control Assoc., 17(7):470-473, July 1967.

The power plant designer today has the tools at hand which enable him to predict with an adequate degree of accuracy the effect of different stack heights on ground level concentrations of the gaseous pollutants emitted from power plant stacks. Use of tall stacks will make it possible in most cases to build larger power plants at any particular site than are in service now and still operate them satisfactorily from the standpoint of air pollution. On the other hand, atmospheric pollution considerations may make it necessary at some sites to put a finite limitation on the maximum capacity that can be installed. APTIC #7843.

22. Nelson, F. and L. Shenfeld.
ECONOMICS, ENGINEERING, AND AIR POLLUTION IN THE DESIGN OF LARGE CHIMNEYS. Preprint. (Presented at the 58th Annual Meeting, Air Pollution Control Assoc., Toronto, Canada, June 20-24, 1965).

A discussion of the methods used to determine the most economic design of chimney for a new thermal power station or large industrial plant is presented, with the objective that ground level concentration of pollutants will be kept at a minimum. Attention is paid to the geography and climatology of the site, with special reference to the frequency and height of inversions and the prevailing wind direction and speed. A method is illustrated in using a large thermal power station as an example. The maximum sulphur dioxide concentrations at ground level are computed for several chimney heights and gas exit velocities. The values of these sulphur dioxide concentrations; the capital cost of the chimney, the pumping costs, and the gas pressures within the chimney are considered in selecting a suitable chimney height and a gas exit velocity which will meet most economically the stated objective. The paper deals primarily with chimneys for industrial or power boiler plants of maximum continuous rating greater than 450 million Btu/hr (about 450,000 lbs. of steam/hr), or to chimenys serving furnaces burning fuel at a maximum rate greater than 50,000 lbs/hr of coal, or 30,000 lbs/hr of oil. For chimneys serving plant with smaller heat inputs, chimney selection by reference to Clean Air Act 1956, Memorandum on Chimney Heights is suggested. APTIC #0687.

23. Nester, K.
STATISTICAL FREQUENCY DATA ON MAXIMUM CONCENTRATIONS OF STACK EMISSIONS AS BASED ON SYNOPTIC WEATHER OBSERVATION. Staub (English Transl.), 26(12):13-16, Dec. 1966.

On the basis of hourly meteorological observations and by means of propagation types according to Turner and of diffusion parameters characteristic of these types, maximum concentrations at ground level and their distance from a chimney were calculated for various times. From these concentrations frequency graphs were plotted separately for brick chimneys of the following heights: 60 m, 100 m, and 140 m. It is thus possible to make a comparison with graphs which are obtained when the average values for diffusion parameter given in VDI Regulation 2289 are used in the calculation, and when changes in wind velocities in a given period are only taken into consideration. APTIC #4812.

24. NEW JERSEY AIR POLLUTION CONTROL CODE (Chapter VIII, Control and Prohibition of Air Pollution from Sulfur Compounds in the Form of Gases, Vapors, or Liquid Particles). New Jersey State Department of Health, Trenton. (March 1, 1967). 10p.

This chapter of the New Jersey Air Pollution Control Code is divided into two sections. The first section provides definitions of terms and the second lists the regulations for sulfur compounds. Two tables are included for the determination of stack heights at less than 200 feet and over 200 feet. APTIC #6695.

25. Nonhebel, G.
BRITISH CHARTS FOR HEIGHTS OF INDUSTRIAL CHIMNEYS. Intern. J. Air Water Pollution, 10:183-189.

A precis is given of the Memorandum on Chimney Heights issued by the British Ministry of Housing and Local Government in 1963. The purpose of the Memorandum is to assist local authorities to determine the minimum acceptable height for new chimneys for industrial plants not coming under the jurisdiction of the Alkali Inspectorate, and for SO_2 emissions from 3 to 1800 lb/hr. Examples are given of charts relating height of chimney with SO_2 emission rate and for additional height required when downdraught from adjacent buildings is to be expected. The basic height of chimneys for oil-fired plant is 10 per cent higher than for coal-fired plant. Minimum effluent velocities are stated. Notes are given of the technical work leading to the Memorandum. The average maximum ground-level concentration of SO_2 from the recommended heights is 16 pphm by volume (0.45 mg/N cum) for 3-min sampling time when calculated from the Bosanquet-Sutton equations. Some account is taken of contaminants other than SO_2. The assistance given by the Memorandum has been widely praised by local authorities after two years' experience. APTIC #1459.

26. Pearson, R. B. and Leason, D. B.
INSULATION OF TALL BRICK-LINED CONCRETE CHIMNEYS. J. of the Inst. of Fuel, 39(301):68-78, 1966.

An account is given of a study crried out some years ago on the chimneys at Belvedere Power Station. The heat losses from the chimney were studied theoretically and experimentally with a view to minimizing acid deposition within the chimney. The difficulties in obtaining experimental results from a large chimney are emphasized and the results discussed. The theoretical findings suggested that a substantial reduction in heat losses could be achieved if the air annulus was filled with vermiculite. The practical realization of this insulated chimney is described together with the subsequent measurements of gas and lining temperatures which permitted the more economic operation of the boilers without increasing the likelihood of acid deposition. APTIC #9469.

27. Pitman, C. W.
THE CONTROL OF CHIMNEY HEIGHTS. Public Health Inspector (London), 74(11):479-485, Aug. 1966.

Atmospheric pollution resulting from fuel combustion has a seriously harmful effect upon the environment and upon objects both animate and inanimate within it. Limited by the boundaries of present knowledge, the current approach is to ensure that polluting gases are discharged at heights adequate to minimize their effects at ground level. The consequences of this policy have financial implications for industrialists and others whose chimneys are now required to be higher, for public health reasons, than combustion engineering alone would necessitate. There is, however, in the Drainage of Trade Premises legislation a good precedent for practice of such measures. The sympathy of town planning and amenity interests is of fundamental importance, and, once gained, an apparent conflict of interest can be turned to mutual advantage, thus bringing double benefit to the community. There is scope for continuing research to discover practical methods of removing sulphur from fuels; until this has been achieved, local authorities and the general public require to be educated into understanding if the need for, and acceptance of, chimneys of greater heights than have been considered necessary in recent practice. There are good reasons too, for an extension of control of chimney heights beyond the scope of present legislation, which stops short of what is considered necessary in present day conditions. APTIC #1515.

28. Pooler, Francis, Jr.
POTENTIAL DISPERSION OF PLUMES FROM LARGE POWER PLANTS. PHS Publication No. 999-AP-16, 1965, 13p.

Expected ground-level concentrations resulting from emissions from large power plants are discussed for three meteorological situations considered to be most likely to result in significant concentrations. These situations are (1) high wind; (2) inversion breakup; and (3) limited mixing layer with a light wind. Effects of increasing stack height are discussed for each situation. Numerical examples based on calculations included as an appendix are shown. APTIC #0846.

29. Scores, R. S.
PLUMES FROM TALL CHIMNEYS. Weather, 10(4):106-109, 1954.

Plume behavior is discussed for a wide range of stack gas and meteorological conditions. The most effective method of dispersion is to emit hot stack gases from a tall, wide stack.

30. Sherlock, R. H. and E. J. Lesher
ROLE OF CHIMNEY DESIGN IN DISPERSION OF WASTE GASES. Air Repair, 4(2):13-23, Aug. 1954.

A method is developed for the use of wind tunnel testing of models by which the design of a station building and its stacks can be determined so that the downwash of the smoke plume towards the earth due to aerodynamic effects, can be practically eliminated. Knowledge gained in the wind tunnel concerning the behavior of the plume close to the plant can be used as a starting point for the computation of ground concentrations of gas. The results are more reliable than those based on the usual assumption of a point source. APTIC #5854.

31. Smith, M. E.
REDUCTION OF AMBIENT AIR CONCENTRATIONS OF POLLUTANTS BY DISPERSION FROM HIGH STACKS. Combustion, 38(10):23-27, April 1967. In: THE TALL STACK FOR AIR POLLUTION CONTROL ON LARGE FOSSIL-FUELED POWER PLANTS, pp. 5-11, 1967.

The value and limitations of high stacks are outlined together with the unresolved questions upon which the ultimate value depends. A tall stack in open, uncomplicated terrain will reduce the local ground-level concentrations of gases or small particulates. The degree of reduction depends upon the stack height, the distance from the source, and the meteorological conditions and is accomplished by giving natural turbulence an opportunity to dilute the pollutant before it reaches the ground-level receptors. A stack located in open terrain converts the least favorable meteorological condition to the most favorable. For all practical purposes, a plume emitted at a reasonable height above the ground in an inversion remains aloft indefinitely. Stacks do not eliminate a pollutant, but distribute it in a different way. The upper limit to the maximum stack height and size involves the diminishing improvement with height, cost, construction difficulty, and aircraft hazards as well as the amount of pollutant in the emission, the frequency of unfavorable meteorological conditions, and the acceptable concentrations. There are also a number of unresolved questions such as the prediction of plume rise, large-scale patterns of atmospheric flow associated with terrain features, and the "half-life" of contaminants such as SO_2. The power industry has been able to reduce the ground-level contamination more effectively and more economically than by almost any other method. APTIC #2770.

32. Smith, M. E.
THE TALL STACK. Mech. Eng., 90(2):20-22, Feb. 1968.

The tall stack as a partial solution to air pollution problems is described. Some of the real and imagined limitations of the tall stack are discussed. One purely fictional criticism suggests that a tall stack merely transfers a pollution problem from one location to another. While it is true that a change in wind patterns with height may bring pollutants to the ground at a somewhat different location, a higher stack will invariably produce lower ground-level concentrations at all locations affected. Tall stacks do not actually reduce the total amount of pollutants in the atmosphere nor do they decrease concentrations at very distant receptors. The most controversial technical issues concerning stacks involve the presence of a capping temperature inversion above a layer in which vertical mixing can occur. One of these situations is called an "inversion break-up fumigation" and it is most easily visualized at the mixing of a plume in a shallow layer between the ground and the inversion lid aloft. The other phenomenon is supposed to occur in cities when a plume is emitted beneath a similar capping inversion that is typically present during air pollution episodes. There is a growing body of evidence indicating that inversion break-up fumigation in open country may almost never occur with well-designed tall stacks. Initial data from a TVA project support the idea that fumigations from tall stacks produce concentrations no higher than those found in ordinary meteorological conditions. APTIC #9124.

33. Sporn, P. and T. T. Frankenberg
PIONEERING EXPERIENCE WITH HIGH STACKS ON THE OHIO VALLEY ELECTRIC CORPORATION AND AMERICAN ELECTRIC POWER SERVICE CORPORATION. Preprint, (Presented at the International Clean Air Congress, London, 4-7 Oct., 1966). 7p.

The two Ohio Valley Electric Corporation plants with capacities of 1200 and 1000 MW were pioneering ventures in many ways. During their design stage, the ten largest thermalelectric plants operating in the United States had an average size of less than 600 MW. By 1963 there were 17 plants in operation, each exceeding 1000 MW. The wind tunnel work and gas diffusion calculations leading to the selection of 683-foot stacks for the larger plant and 535-foot for the other is described. Dustfall and SO_2 concentration studies in the field began prior to operation and continued for three years after full commissioning of the plants. Data obtained were used in evaluation of the diffusion equations, and to judge the correctness of certain mathematical models covering transient situations. Experience obtained in operating and maintaining these pioneer stacks led to modifications in the design of the 825-foot stacks for Cardinal Plant near Brilliant, Ohio which will be commissioned in 1966. APTIC #1796.

34. Squires, Arthur M.
THE CONTROL OF SO_2 FROM POWER STACKS. PART I - THE REMOVAL OF SULFUR FROM FUELS. Chem. Eng., 74(23):260-268, Nov. 6, 1967.

The first of four articles on the curbing of air pollution through the control of sulfur dioxide emission from power station flue stacks looks into the technology and economics of removing sulfur from fuels before they are burned. The progress of work on desulfurization of fuel oil and coal both here and abroad is traced. While desulfurization processes have been developed, they do not appear to offer an early, cheap solution to the SO_2 problem of the power station. APTIC #8917

35. Stone, G. N. and A. J. Clarke
BRITISH EXPERIENCE WITH TALL STACKS FOR AIR POLLUTION CONTROL ON LARGE FOSSIL-FUELED POWER PLANTS. Preprint. (Presented April 27, 1967, American Power Conference, Illinois Institute of Technology.)

Some of the more interesting steps in the development of the tall stack policy were traced and the factual data and practical observations which support and justify the CEGB's approach to this controversial subject summarized. Peak SO_2 concentrations at any one point at ground level are very transient and infrequent, and their magnitudes are predictable to a reasonable degree of accuracy. No meteorological situation has been encountered in which the short-term peak concentrations are more than double those in neutral conditions; a fact that can readily be allowed for in the selection of stack heights. Hot plumes from tall stacks rise high in stable atmospheric conditions and make virtually no contribution to ground level pollution. The higher the stack the greater the plume rise, and the more frequently will stable layers in the lower atmosphere shield the ground surface. Modern power plants with tall stacks can operate over extended periods without making any material addition to the general level of pollution in the areas in which they are situated. All the power plants over a large geographical area can collectively operate without any detectable influence on the trend of ground level SO_2 concentrations in the area. APTIC #5062.

36. Szwed, H.
(DISSEMINATION OF ATMOSPHERIC POLLUTION BY INDUSTRIAL CHIMNEYS). ROZPRZESTRZENIANIE ZANIECZYSZCZEN W ATMOSFERZE PRZEZ KOMINY PRZEMYSLOWE. Ochrona Pracy (Warsaw), 21(6):19-23, June 1966.

The dissemination of industrial pollutants within the upper layers of the atmosphere by stacks is discussed. The influence of meteorological conditions and the relationship of the height of the chimneys to the concentration of pollutants are described. APTIC #1533.

37. Thomas, F. W., Carpenter, S. B. and Gartrell, F. E. STACKS -- HOW HIGH? J. Air Pollution Control Assoc., 13(5):198-204, May 1963.

Tennessee Valley Authority experience in the performance of stacks for dispersal and dilution of power plant wastes are reviewed. Basic stack height criteria; stack height estimation by empirical extrapolation from data on existing plants and from mathematical diffusion analyses; relative effectiveness of stacks in principal dispersion models for neutral condition-coning plume and for inversion condition-fanning plume; the beneficial effect of heat emission in inversion conditions and in unstable, conditions-looping plume; mathematical formulation of plume rise, implications of common formulae, and estimate from TVA data, and efflux velocity are covered. APTIC #3731.

38. Thomas, M. D., G. R. Hill and J. N. Abersold
DISPERSION OF GASES FROM TALL STACKS. Ind. Eng. Chem., 41:2409-2417, Nov. 1949.

The theoretical equations of Bosanquet and Pearson and Sutton for the dispersion of smoke from factory chimneys have been solved in terms of the conventional units of the smelting industry for the elimination of sulfur dioxide from 4 smelters. A large mass of field data for sulfur dioxide in the atmosphere, obtained by means of automatic recorders, has been evaluated in the form of Cu to M ratios, where C is the field concentration, M is the mass emission of sulfur from the plant, and u is the wind velocity. The data for tall stacks at Selby, Calif., Tacoma, Wash., Garfield, Utah, and El Paso, Tex., agree well with the theoretical equations, when values of the diffusion coefficient of 0.05 to 0.07 are used and the exponent of the distance, x, in Sutton's equation is 2 (n - 0). A somewhat smaller exponent may be needed to satisfy the data for the short stacks at Selby and El Paso. The theoretical curves and confirming data illustrate forcefully the beneficial effects of use of tall stacks in dispersing air contaminants from factories. Maximum ground concentration varies inversely with square of stack height. This results in lower peak and lower average concentrations from the tall stack and higher percentages of time when air is free of contamination. High temperature of smoke elimination increases effective stack height and improves dispersion.

39. TUFTS COVE - DUAL FIRING AND CYCLONE FURNACES FOR 100 MW UNIT NOVA SCOTIA. Eng. Boiler House Rev., 81(8):234-238, Aug. 1966.

Tufts Cove thermal generating station was commissioned on September 30, 1965 as a new power source for Nova Scotia in Canada. The steam generating unit is a Babcock & Wilcox cyclone-fired radiant type boiler having a continuous steaming capacity of 725,000 lb. hr. The design pressure of the unit is 2,100 lb/sq in g with operating steam conditions of 1,850 lb/sq in g and 1,010 F at the superheater outlet and a reheat steam temperature of 1,010 F at the reheater outlet. The overall efficiency of the unit, at a steam flow of 650,000 lb/hr is 90.3 per cent when burning Cape Breton coal. This cyclone fired steam generating unit was selected for Tufts Cove Station on its suitability for the burning of Cape Breton coal. The flue gas leaving the air heater passes through an electrostatic precipitator which has a collection efficiency of 95 percent. The dust loading of the flue gas leaving the precipitator is guaranteed not to exceed 0.25 lb of dust per 1,000 lb of flue gas adjusted to 12 per cent CO_2. The steam generating unit is equipped with a Diamond automatic sequentially-operated, steam blowing sootblower system with 11 retractable blowers in the superheater-reheater section, 2 non-rotating retractable furnace wall blowers. The fly ash collected by the precipitator is of a very fine grain size, approximately 95 per cent under 50 microns in size. Due to the fineness of this ash and the disposal problem it may present, the unit is equipped with an ash refiring system. This system conveys the fine precipitator ash back to the cyclone furnaces, where it is melted back to liquid and disposed of as slag into the slag tank. The most prominent physical feature of the plant site is the 500 ft high chimney, which consists of a steel reinforced concrete column surrounding an independent brick lining. The height was decided upon following extensive wind tunnel tests on scale models of the surrounding terrain carried out to determine the effect of flue gas dispersal of various chimney heights. The final cost of the project will be approximately 17,000,000. APTIC #4224.

40. Walters, D. F. and Martin, D. O.
AN EVALUATION OF THE AIR POLLUTION ASPECTS OF THE PROPOSED STEAM-ELECTRIC PLANT AT OAK PARK, MINNESOTA. Preprint. 1965.

The installation and operation of the 550,000 kilowatt steam-electric plant at Oak Park, Minnesota, will generate large quantities of air pollutants, principally sulfur dioxide, nitrogen oxides, and particulate matter. A 785-foot stack will be installed to permit dispersion and dilution of gaseous pollutants. Calculations indicate that ground level concentration of sulfur dioxide may cause acute damage to vegetation. However, existing information is inadequate to predict with assurance whether long-term chronic effects will be experienced by long-lived vegetation such as trees. It is expected that the human perception threshold for SO_2 will be exceeded occasionally. Inversion breakup fumigation may produce ground level concentrations exceeding the human perception threshold at distances of ten miles or more. The installation and operation of a second unit of 750,000 kilowatt capacity will more than double air pollution emissions. If the 550,000 kilowatt unit is built and operated, a SO_2 monitoring network should be activated. This will assist in determining the effects of SO_2 on the surrounding vegetation and people, as well as provide guides for future installation design. Prevailing winds in this area are such that air pollutants will often be carried into Wisconsin. Therefore, officials of that State should take part in air pollution activities connected with the proposed plant. Plans and studies should be started now to obviate future air pollution problems indicated by plans for expansion of this plant beyond the initial 550,000 kilowatt capacity. APTIC #1842.

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ATMOSPHERIC PHENOMENA

41. Andreyev, P. I.
A COMPARATIVE STUDY OF EXPERIMENTAL AND THEORETICAL ATMOSPHERIC POLLUTION CONCENTRATIONS RESULTING FROM LOW LEVEL EMISSIONS. In: Survey of U.S.S.R. Literature on Air Pollution and Related Occupational Diseases. Translated from Russ. by Levine, B. S., Nat. Bureau of Standards, Washington, D. C., Inst. for Applied Tech., 3:64-69, May 1960.

Formulas for the computation of expected concentrations of gases discharged by industrial establishments were derived on the basis of the theory of turbulent diffusion in the atmosphere. One is for the calculation of ground level gas concentration along the axis of a flow coming from a point source (organized) and the other is for the calculation of ground level gas concentrations emanating from a linear source (unorganized). Both formulas are applicable to the determination of theoretical concentrations of gases and highly dispersed dust. A comparison of theoretical concentrations with the experimental data was presented. The formulas given for either high or low pollution sources will present an adequate picture of the actual process of pollution diffusion in the atmosphere. These formulas may be utilized in dealing with problems arising in planning production and manufacturing plants and in conducting scientific research. APTIC #8143.

42. Arai, K.
THE PROBLEMS OF DIFFUSION IN AIR POLLUTION. Text in Japanese. Journal of the Fuel Society of Japan (Tokyo), 44(461):606-617, Sept. 1965.

Meteorological conditions (wind velocity, temperature and atmospheric stability), topography, and building height are considered in connection with problems of emission. Emission speeds of more than twice the wind velocity are desirable for effective diffusion. Three equations for atmospheric diffusion are shown: the Sutton, the Bosanquet-and-Pearson, and the British Meteorological Bureau (used most in Japan). An equation for effective stack height is also given. Although ferro-concrete stacks are inexpensive and their usual height is less than 100 meters due to the prevalence of earthquakes in Japan, higher steel stacks are more effective for diffusion. Wind tunnel tests and industrial sites (existing or planned) are discussed. The use of better quality fuel and the elimination of contaminants should be considered of primary importance in the fight against industrial air pollution. APTIC #4383.

43. Ashley, E. C. and B. Kalmon
THE VALIDITY AND USE OF SUTTON'S EQUATION AS APPLIED TO STACK EFFLUENTS. AEC (Atomic Energy Commission) Air Cleaning Conf., 8th, Oak Ridge, Tenn., 1963, pp. 664-673.

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A simple determination of the maximum ground level concentrations of radioactive stack gases can be made by using the basic Sutton equation. Using simple assumptions, a correlation coefficient of 0.72 at a 95% confidence level was found between the calculations and sample results. APTIC #3144.

44. ASME Standard 1968. GUIDE FOR PREDICTING DISPERSION OF AIRBORNE POLLUTANTS. The American Society of Mechanical Engineers, 345 E. 47th., New York City.

The result of work dating back to December, 1964, by a team of engineers, scientists, and meteorologists, the guide is designed to help air pollution controllers estimate the concentration of harmful pollutants at ground level for various height stacks. This guide, which takes into account the capacity of the atmosphere to dilute gases and particulate matter, presents approximations for use in dealing with various terrains and weather conditions.

45. Barad, M. L.
ATMOSPHERIC DISPERSION. (In: Atmospheric Pollution). Air Force Cambridge Research Center Hanscom (L.G.) Field, Mass., pp.8-24. (Presented at the Interdisciplinary Conference on Atmospheric Pollution, Santa Barbara, Calif., June 1959).

Technical findings which potentially are most applicable to the air pollution problem, particularly research results which were produced within the previous eight or nine years, are summarized. Dispersion in both nonuniform and in uniform wind fields and terrain, and the effects of sources and sinks are considered. APTIC #3767.

46. Barry, P. J. and R. E. Munn
THE USE OF RADIOACTIVE TRACERS IN STUDYING MASS TRANSFER IN THE ATMOSPHERIC SURFACE BOUNDARY LAYER. Symposium on Boundary Layers and Turbulence, Kyoto, Japan, Sept. 19-24, 1966.

Certain natural surfaces such as snow act as almost perfect sinks for some radioactive gases. Experiments in which tracers of differing molecular diffusivities are released simultaneously permit inferences to be drawn about the importance of the lowest few mm of the atmosphere in regulating vertical fluxes. Twelve field experiments are described in which iodine-131 and tritiated water vapour gases were released simultaneously over snow during mostly smooth-wall turbulent conditions. The resistance to vertical mass transfer (the ratio of concentration at 30 cm to flux) was larger for iodine than tritium. Mass transfer coefficients are calculated. They are larger for tritium than for iodine; their ratio is equal to the ratio of molecular diffusivities raised to the power of about 0.8, and there is no trend with roughness Reynolds number. The drag coefficient is larger and increases with Reynolds number. The mass transfer coefficient is compared with that proposed by Sverdrup for estimating evaporation from large open water surfaces. The comparison showed little agreement between the the coefficients. APTIC #8529.

47. Berlyand, M. E.
TO THE THEORY OF THE INDUSTRIAL EMISSION DISPERSION IN THE ATMOSPHERE OF A COASTAL ZONE. Idojaras, 71(2):65-72, Mar.-Apr. 1967. (Presented at the Symposium on the Meteorological Questions of Air Pollution, Budapest, Hungary, Nov. 10-11, 1966.)

The interaction of stack gases and plumes with the atmosphere depends heavily on meteorological conditions. Theoretical, field, and experimental work was done on the diffusion of gases from stacks as high as 300m; variables included release height, terrain shape, distance from source, and wind speed. A wind speed was found in each situation where the resultant ground concentration with a maximum, and a formula was derived to predict this. APTIC #9968.

48. Berlyand, M. Y., Y. L. Genikhovich and V. K. Dem'yanovich
SOME TIMELY PROBLEMS IN THE INVESTIGATION OF ATMOSPHERIC DIFFUSION. Trudy Glavnoy Geofizicheskoy Observatorii (Transactions of the Main Geophysical Observatory) (Translated as JPRS 34,719) 3-22, 1965.

The general form of the equation of stationary diffusion was investigated, taking into account variations of wind direction and the effect of averaging of concentrations. On the basis of the results of numerical solution of the diffusion equation an analysis is made of the influence of the vertical distribution of the coefficients of the equation on its solution. The problem of the diffusion of an admixture in an area of hilly relief is considered and the results of numerical computations for gently sloping topography are presented. There is a discussion of the problems involved in taking into account the initial rising and heating of the admixture and a numerical solution of this problem is given. APTIC #2993.

49. Bierly, E. W. and E. W. Hewson
SOME RESTRICTIVE METEOROLOGICAL CONDITIONS TO BE CONSIDERED IN THE DESIGN CF STACKS. J. Appl. Meteorol., 1(3):383-390, Sept. 1962.

There are several restrictive meteorological conditions that are of great importance in the design of stacks. The conditions considered are fumigation, aerodynamic downwash, looping and trapping. Each condition is explained and formulae are given for the computation of ground level concentrations. Methods for determining the percentage of occurrence of these restrictive conditions from observed data are also discussed very briefly. APTIC #0035.

50. Bodurtha, F. T., Jr.
THE BEHAVIOR OF DENSE STACK GASES. J. Air Pollution Control Assoc., 11(9):431-436, Sept. 1961.

The present study demonstrated that dense stack gases descend rapidly to the ground. The results indicate that dense stack gases should be discharged vertically upward from a stack with the minimum practicable diameter. This minimum diameter results in the maximum stack gas velocity for a given flow rate.

In some cases, however, collection equipment may be necessary to prevent pollution or a potential safety hazard. In addition, these tests emphasize that previously-existing atmospheric dispersion equations cannot be used with reliability to estimate the concentration of dense stack gases at the ground. The governing effect of buoyancy on the behavior of a stack plume was confirmed. APTIC #5840.

51. Bodurtha, F. T., Jr.
CONTROL OF POWER PLANT STACK EMISSIONS FOR CLEAN AIR. Proc. Am. Power Conf., 27: 399-411, April 1965.

Atmospheric phenomena are reviewed in the context of establishing control of stack emissions and setting concentration standards. Primary concern is with ground level SO_2 concentration and with this as a focal point the following topics are stressed: normal dispersion, temperature inversion, topography and fog. Mathematical concepts of dispersion theory are discussed and techniques in the use of dispersion equations to calculate maximum concentrations or stack height are provided in an appendix. APTIC #4334.

52. Bodurtha, F. T.
BACKGROUND AND BASIS OF ASME STANDARD, "RECOMMENDED GUIDE FOR THE CONTROL OF DUST EMISSION--COMBUSTION FOR INDIRECT HEAT EXCHANGES" - APS-1. In: Discussion on ASME Standard APS-1 on Dust Emission From Indirect Heating Furnaces, New York, Amer. Soc. Mech. Eng., 1966, p. 1-11.

The background and basis for the first standard of the ASME Air Pollution Standards Committee is described. A discussion relates dustfall and suspended dust from indirect heat exchangers, plume rise and dispersion, and multiple stacks, to the methods of determining ground level concentrations. Limitations are given. An attempt is made to maintain a measure of flexibility by supplying a "cap" on emission limit, and provision for stack height. APTIC #7259.

53. Boer, W.
(THE APPLICATION OF METEOROLOGICAL DATA IN TOWN PLANNING, IN RELATION TO PROBLEMS OF AIR POLLUTION.) DIE ANSENDUNG METEOROLOGISCHER UNTERLAGEN BEI DER STADTPLANUNG IN HINSICHT AUF PROBLEME DER LUFTVERUNREINIGUNG. Proc. (Part I) Intern. Clean Air Cong., London, 1966. pp. 79-81.

Only a drastic reduction of "specific emission" will finally solve the problem of clean air. Meteorological data and knowledge may, however, be usefully applied to the solution of single problems. It is important to have statistics of temperature inversions near the ground, to know the structure of the wind field near the ground and to work out actual and prognostic "plans of pollution" by means of the formulas of atmospheric diffusion. APTIC #2012.

54. Bosanquet, C. H.
THE RISE OF A HOT WASTE GAS PLUME. Jour. Inst. Fuel., 30:322-328, 1957.

It is assumed that when a cloud of hot gas is rising the total heat content and total upward momentum are unaffected by dilution with atmospheric air. It is also assumed that the upward momentum increases at a rate proportional to the heat content. Rate of dilution is assumed to be proportional to the surface area of the cloud multiplied by a function of the wind velocity and the velocity of the cloud relative to the surrounding atmosphere. From these principles an equation is developed for finding the track of hot waste gas rising from a chimney in a wind of any velocity. The height to which the waste gas rises depends on both its heat content and its exit momentum and tables are given for calculating the combined effect. It is shown that if the temperature gradient in the atmosphere is less than adiabatic the smoke will not continue to rise indefinitely but will eventually settle down at a definite height.

55. Briggs, G. A.
A PLUME RISE MODEL COMPARED WITH OBSERVATIONS. J. Air Pollution Control Assoc., 15(9):433-438, Sept. 1965.

Dimensional arguments are used to predict plume rise for buoyant plumes in both stable and neutral air, for both calm and windy conditions. Dominant terms are assumed to be wind speed buoyancy, flux (proportional to heat efflux) and a stability parameter (proportional to potential temperature gradient). Observations presented support the dimensional analysis predicitions, except that for final rise in a neutral atmosphere they are adequate only for a conservative estimate of rise. The method is extended to predict maximum ground concentration of effluent gases in the worst situations (windy neutral and fumigation) for open country, valleys and canyons. These predictions are compared with limited observations. APTIC #0725.

56. Brummage, K. G.
THE CALCULATION OF ATMOSPHERIC DISPERSION FROM A STACK. CONCAWE, The Hague, Netherlands, Aug. 1966.

A critical appraisal is made by the CONCAWE Working Group on Stack Height and Atmospheric Dispersion of published methods for calculating the ground level concentration of a gas issuing from a stack. The process of dispersal of gas from a stack is considered in two consecutive stages, the initial rise of the gas by virtue of its momentum and buoyancy, and then its spread downwind from the effective source height to which it has risen. After a full study of both aspects, the method of calculation of the maximum ground level concentration is considered. Of the dispersion equations considered, that originally due to Sutton was considered to be the most convenient, and to be of sufficient accuracy. The Sutton formulation leads to an equation for the maximum ground level concentration at an average wind speed u. A simple relationship in best agreement with the experimental data is given. The main problem in the calculation of maximum ground level concentration from a stack is the evaluation of plume rise. More experimental and theoretical work is needed to choose between the various approaches that are available, especially when the gas and heat outputs are high. APTIC #6558.

57. Brun, M.
(DIFFUSION OF POLLUTANTS IN THE ATMOSPHERE. METHODS OF CALCULATING THE HEIGHT OF INDUSTRIAL CHIMNEYS IN EFFECT IN GERMANY, UNITED STATES, GREAT BRITAIN, HOLLAND AND RUSSIA). DIFFUSION DES POLLUTANTS DANS L'ATMOSPHERE. METHODES DE CALCUL DE LA HAUTEUR DES CHEMINEES INDUSTRIELLES EN VIGUEUR EN ALLEMAGNE, ETATS-UNIS, GRANDE BRETAGNE, HOLLANDE ET RUSSIE). Centre Interprofessionel Technique d'Etudes de la Pollution Atmospherique, Paris, France, Fr. (Rept. No. CI 271). C.I.T.E.P.A. Doc. No. 24.

A comparison is made of the methods of calculating the height of industrial chimneys in the various countries involved. In principle, all of the methods are applications of Sutton's dispersion formulas, although the choice of meteorological parameters may be made arbitrarily. Differences appear when the elevation of the plume is used rather than the actual height of the chimney. Different values for the permissible concentration at ground level adopted by different countries also causes a divergence. A comparison is given of the effect on each of the methods of the power of the installation, the sulfur content of the fuel, the velocity of the smoke at emission, the wind velocity, and the background pollution. Numerous tables are given comparing the different methods of calculation and the reasoning in back of them. APTIC #6775.

58. Carpenter, S. B., J. A. Frizzola, M. E. Smith, J. M. Leavitt and F. W. Thomas.
REPORT ON FULL-SCALE STUDY OF PLUME RISE AT LARGE ELECTRIC GENERATING STATIONS. Preprint. (Presented at the 60th Annual Meeting, Air Pollution Control Assoc., Cleveland, Ohio. June 11-16, 1967).

Plume rise data were collected at six coal-fired, steam-electric generating stations within the TVA system over a 2-year period. Unit ratings ranged from 172 to 704 megawatts with stack heights varying from 250 to 600 feet. An instrumented helicopter and special photographic equipment were used to obtain 1,580 separate plume observations and significant related meteorological parameters during stable, neutral, and slightly unstable conditions. The 1,580 observations were resolved and consolidated into 133 composite observation periods covering 30 to 120 minutes. Meteorological parameters and other compiled input data were entered into four principal equations for calculation of plume rise, and calculated plume rise values were compared with observed values. Most equations overestimated plume rise in low wind speed. For moderately high wind speeds, the ASME and Concawe equations gave best fit. APTIC #6373.

59. Carson, J. E. and H. Moses
THE VALIDITY OF CURRENTLY POPULAR PLUME RISE FORMULAS. In: Proc. of the USAEC Meteorological Information Meeting held at Chalk River Nuclear Lab., Sept. 11-14, 1967. Mawson, C. A. (ed.)

The ground-level concentrations of pollutants downwind of a tall chimney decrease as the effective height of the stack increases. The effective height of the stack is the actual height plus the rise of the plume centerline due to momentum and buoyancy of the effluent. Over twenty plume rise formulas have been proposed, but none is widely accepted due in part to a lack of sufficient plume rise data for testing. In this paper, 711 plume rise observations are used to test the ability of fifteen of the published formulas to predict plume rise. The plume rise data were obtained from stacks whose heat emission rate varied over four orders of magnitude. APTIC #10048.

60. Chalker, W. R.
USE OF STACK DISPERSION ANALYSIS TO DETERMINE OPTIMUM STACK SIZE.
Petro/Chem. Engr., 39(6):35-36, 38, May 1967.

Atmospheric dispersion calculations which provide a tool to relate the stack emission to the resultant downwind concentrations are given. The response of the receptor, which is the most important factor, is a function of the type, quantity, and source characteristics of the contaminant discharged into the air and the meteorological conditions existing at the time. Since there is a wide range of effects on the receptors, the concentrations which cause these effects must be known. In this work the empirical Bosanquet-Pearson dispersion equation was used. To establish the effective stack height, a key factor in the Bosanquet-Pearson equation, the Davidson-Bryant velocity rise equation is used. Various combinations of stack height, diameter, and collection efficiency are possible to obtain a permitted discharge which makes the selection a question of cost. Wind tunnel experiments are indicated as a guide in orienting buildings and locating and designing stacks where wind eddies from buildings may carry gas back to the ground level. APTIC #6138.

61. Charash, E.
THE ESTIMATION OF EFFLUENT CONCENTRATIONS FROM AN ELEVATED CONTINUOUS SOURCE. Australian Atomic Energy Commission, Research Establishment, Lucas Heights, AAEC/TM307, [26]p., Dec. 1965. [12] refs.

From fundamental theory and empirical knowledge of the structure of atmospheric turbulence spectra, diffusion equations are developed with parameters which are adjustable so as to reflect the influence of varying surface roughness as well as a wide range of stability conditions. Instructions are given for practical applications of the diffusion equations which should be valid for travel distances of about a mile at heights greater than fifty feet above ground. APTIC #10521

62. (CHIMNEY PLUME RISE AND DISPERSION.) ELEVATION DES PANACHES DE FUMEES ET DISPERSION. Centre Interprofessionel Technique d'Etudes de la Pollution Atmospherique, Paris, France. (Rept. No. CI 316) (C.I.T.E.P.A. Doc. No. 24, 1967). Fr.

The symposium held at Letherhead, England on October 7, 1966 on chimney plume rise is reported which includes two surveys of the SO_2 in the neighborhood of electric power houses and the chimney plume rise under various meteorological conditions. The height of the plume was measured in one case by the signal reflected from the plume of a luminous beam directed at the plume from the ground. The use of lidar, which uses a laser beam instead of light, permits the observation of an invisible plume 1200 meters from the source. It also detects the level of inversion. The lidar permits the total scanning of a plume in 3 min. The SO_2 values for dispersion were made for different plume heights, but were not given. Two formulas were derived; one gives the height of plume of smoke and the other the maximum concentration at ground level. APTIC #6777.

63. Clarke, J. F.
A SIMPLE DIFFUSION MODEL FOR CALCULATING POINT CONCENTRATIONS FROM MULTIPLE SOURCES. J. Air Pollution Control Assoc., 14 (9): 347-352, Sept. 1964.

Four meteorological parameters were combined with Cincinnati's CAMP source emission inventory data. Accepted diffusion coefficients and readily available meteorological data were utilized in a model simple enough to allow calculations without the aid of an electronic computer. Dispersion coefficients, effective stack heights, wind direction and velocity, and depletion were considered. The results were considered to be within the precision of the source inventory. The model has application as a forecasting tool and as an aid to evaluating urban air pollution sources and explaining air quality measurements. It can be simply presented in diagrams of relative concentration (x/Q)and used with source strength data to obtain quick estimates of point concentrations from multiple sources. The variation of concentration due to variations of the meteorological and source parameters is readily obtainable. Application of the model to other locations requires only a change in the presentation of emission data. It is presumed that the model is adaptable to any location within Cincinnati, to other pollutants, and hopefully, to other cities. APTIC #1068.

64. Conner, W. D. and J. R. Hodkinson
OBSERVATIONS OF THE OPTICAL PROPERTIES AND VISUAL EFFECTS OF SMOKE PLUMES. Preprint. (Presented at the 57th Annual Meeting, Air Pollution Control Assoc., Houston, Tex., June 21-25, 1964.)

Detailed observations are reported on the reduction in contrast between targets seen through white experimental plumes of various transmittances, on the contrast between white experimental plumes and their background, and on the great effect of varying conditions of lighting and observation. The variations in plume transmittance for light of different wavelengths and the angular distribution of light scattered by the experimental white plume and oil-burning electric plant plume have also been measured, and estimates of mean particle-size derived therefrom. Trials have been made to ascertain how well observers can be trained to estimate visually, under different conditions, the transmittance of light and dark plumes. APTIC #3546.

65. Conner, W. D. and J. R. Hodkinson
OPTICAL PROPERTIES AND VISUAL EFFECT OF SMOKE-STACK PLUMES. PHS, Cincinnati, Ohio, National Center for Air Pollution Control and Virginia State Coll., Norfolk, Dept. of Physics, PHS-Pub-999-AP-30, 89p., 1967.

Two experimental smoke stacks were constructed to provide test plumes for studies of optical properties and visual effects under a wide range of conditions. Contrast reduction between objects viewed through plumes was used as an index of vision obscuration, and contrast between plumes and their background was used as an index of visual appearance. Results indicate that visual effects are not intrinsic properties of the plumes but vary with the background of the plume and with illuminating and viewing conditions. Variation was much greater with white plumes than with black. Tests conducted with trained smoke inspectors showed that their evaluations of nonblack smoke plumes were significantly influenced by these variations. The angular scattering and transmission characteristics of the experimental plumes were measured and estimates of particle size were made. The study shows that the quantity of aerosols in a plume is evaluated best by its transmittance. Special methods are discussed for objectively measuring the transmittance of smoke plumes. The methods involve telephotometry, photography, and photometry of targets; the use of smoke guides; and laser measurements. APTIC #5060.

66. Csanady, G. T.
SOME OBSERVATIONS OF SMOKE PLUMES. Intern. J. Air Water Pollution. 4(1/2):47-51, 1961.

The plume at Tallawarra power station was photographed many times to obtain the mean position. The observations were plotted in terms of appropriate nondimensional variables and compared with the observations of Bosanquet et al,, as well as the theoretical results of Priestley and Sutton. Within about 1500 ft. from the source good agreement with theory was found. The asymptotic plume height was found to be given crudely by the formula: Z_a=250 F/U^3, where Z_a is asymptotic plume height, U is wind speed, F is flux of buoyancy a variable proportional to heat flux. APTIC #5357.

67. Csanady, G. T.
THE EFFECT OF BUOYANCY ON THE DISPERSAL OF CHIMNEY EFFLUENTS. Preprint. 1967.

The recent consolidation of evidence on the mean path of hot chimney plumes is taken advantage of by calculating mean ground level concentrations, resulting from a plume distributed about a mean position given by the "2/3 power law", in a neutral atmosphere. The calculations show that the maximum value of the concentration occurs in fairly strong winds because in lighter winds the buoyant movements transport the pollutants bodily away from ground level at a rapid enough rate to more than cancel downward diffusion. Application to a typical power station chimney shows that the maximum value of the concentration occurs in fairly strong winds because in lighter winds the buoyant movements transport the pollutants bodily away from ground level at a rapid enough rate to more than cancel downward diffusion. Application to a typical power station chimney shows that the maximum ground level concentration is reduced by buoyancy by a factor of at least 23, as compared to a "cold" plume. APTIC #5356.

68. Davies, P. O. A. L. and D. J. Moore
EXPERIMENTS ON THE BEHAVIOUR OF EFFLUENT EMITTED FROM STACKS AT

OR NEAR THE ROOF LEVEL OF TALL REACTOR BUILDINGS. Int. J. Air Water Pollution, 8:515-533, 1964.

The behaviour of effluent emitted from stacks projecting a few feet above the roof level of reactor buildings at Berkeley and Bradwell nuclear power stations was studied using models in a wind tunnel and a water tunnel. Full-scale plumes from these buildings were also observed under a limited range of conditions; the behavior of model and full-scale plumes was similar when the efflux conditions were similar. The experimental work indicated that the assumption of fairly simple effluent distributions for the purpose of calculating long-term gamma-dose rates would not lead to serious errors.

69. Gartrell, F. E., F. W. Thomas, and S. B. Carpenter
TRANSPORT OF SO_2 IN THE ATMOSPHERE FROM A SINGLE SOURCE. Proc. Symp. Atmos. Chem. of Chlorine and Sulfur Compounds. Cincinnati, Ohio, Geophysical Monograph #3, pp. 63-68, 1959.

Information accumulated by the TVA on atmospheric diffusion was discussed. Difficulty in predicting ground-level concentrations of SO_2 with the existing diffusion formula (Sutton) lead to the investigation of another method of sampling. The helicopter - Titrilog sampling operation is being employed for defining the plume location, geometry and SO_2 concentration. Meteorological parameters would be required in any formula designed to predict SO_2 concentration at ground level some distance from the SO_2 source. APTIC #6823.

70. Gartrell, F. E., F. W. Thomas, and S. B. Carpenter
AN INTERIM REPORT ON FULL-SCALE STUDY OF DISPERSION OF STACK GASES. J. Air Pollution Control Assoc., 11(2):60-65, Feb. 1961.

The Tennessee Valley Authority in cooperation with the U. S. Public Health Service initiated in July 1957 a full-scale study of diffusion of stack gases from large coal-burning power plants. Three-dimensional measurements of dispersion are made by aerial sampling of SO_2 with a Titrilog operated in a helicopter. This report describes equipment and sampling plans. Data from sampling of eight inversion plumes, along with the results of preliminary analyses of these data, are presented. Apparent losses of SO_2 from the plume with time and distance from the source cited. Preliminary investigations of this finding by means of controlled dilution and cooling of flue gas pointed to oxidation of SO_2 as a possible explanation. APTIC #5963

71. Gartrell, F. E., F. W. Thomas, and S. B. Carpenter
ATMOSPHERIC OXIDATION OF SO_2 IN COAL-BURNING POWER PLANT PLUMES. Am. Ind. Hyg. Assoc. J., 24:113-120, Apr. 1963.

Sampling equipment and procedures applicable for use in a helicopter were devised for collecting the separate SO_2 and SO_3 components in progressive plume cross sections at a large coal-burning plant. Samples were collected during a variety of meteorological conditions with particular attention to a wide range of relative humidity. During periods of low humidity, data reveal that oxidation of SO_2 is relatively slow, increasing from 2% at one mile (12 min) to 3% at 6 miles (60 min). With moderately high humidity, oxidation was initially rapid, 22% at one mile (12min). increasing to 32% at 8 miles (96 min). The highest total oxidation, 55%, was observed in a slight mist at 9 miles (108 min). APTIC #2921.

72. Gartrell, F. E., F. W. Thomas, S. B. Carpenter, F. Pooler, B. Turner, and J. M. Leavitt
FULL-SCALE STUDY OF DISPERSION OF STACK GASES. (A Summary Report). TVA, Chattanooga, Division of Health and Safety, and Public Health Service, Cincinnati, Ohio, Division of Air Pollution, Aug. 1964, 110p.

During fiscal years 1958-1962, the Tennessee Valley Authority conducted an air pollution research project under the sponsorship of the Public Health Service. In this project, advantage was taken of unique opportunities for full-scale appraisal of dispersion of air pollutants from large coal-burning, steam-electric generating plants. Advantages offered for diffusion studies included: (1) large isolated sources where intermixture with extraneous pollutants is not significant; (2) complete plant operational data and emission rates; (3) sufficient fly ash emission to provide a visible plume aloft out to distances of 10-15 miles under meteorological conditions of special interest; (4) a helicopter equipped with special instruments for sampling and recording SO_2 concentrations, as well as extensive auxiliary instruments; (5) tower-mounted meteorological instruments for providing basic information on wind and temperature parameters; and (6) computer facilities for data analysis. In addition to the primary studies to determine diffusion parameters, a limited investigation was made of plume rise or effective stack heights. An extensive investigation was made of the oxidation of SO_2 in the atmosphere after emission from the stack. Oxidation was studied with ground-based facilities and also in the plume at various distances and travel times, and under various weather conditions. In the course of this investigation interrelationships among SO_2, H_2SO_4, and fly ash also were studied. APTIC #0023.

73. Gartrell, F. E.
MONITORING OF SO_2 IN THE VICINITY OF COAL-FIRED POWER PLANTS. - TVA EXPERIENCE. Am. Power Conf. Proc., 27:117-123, 1965.

During the relatively short period of approximately fifteen years, TVA has conducted extensive air pollution studies at eight large, modern, coal-fired, steam-electric generating stations as these plants were added to the TVA power system. The plants vary in unit size, stack heights, fuel supply, site topography, and micrometeorology. This paper presents summaries of some of the significant findings of these studies which should be of value in planning air pollution control for large coal-fired power plants. APTIC #1856.

74. Gartrell, F. E., F. W. Thomas, S. B. Carpenter, F. Pooler, B. Turner, and J. M. Leavitt
FULL SCALE STUDY OF DISPERSION OF STACK GASES. PART IV. COROLLARY STUDIES OF SO_2 OXIDATION. TVA, Chattanooga, Div. of Health and Safety and Public Health Service, Cincinnati, Ohio, Div. of Air Pollution, June 1965, 56p.

While the primary objective was determination of the extent of oxidation of SO_2 in a power plant plume, initial investigation under semi-controlled conditions at ground level was considered to offer a number of advantages, particularly some flexibility for varying environmental conditions. Principal phases of the SO_2 oxidation studies are characterized as follows: (1) Develop equipment and techniques for the collection of representative samples of flue gas and fly ash from steam plant ducts and stacks. (2) Collect and analyze sufficient samples of flue gas and fly ash to establish the relative proportions and concentrations of SO_2 and SO_3, as well as pertinent physical and chemical characteristics of fly ash. (3) Develop facilities for controlled dilution and cooling of flue gas simulating atmospheric dispersion and cooling. (4) Develop instrumentation for evaluating changes in sulfur oxides and fly ash subjected to controlled dilution and cooling. (5) Modify instrumentation and techniques developed in the preceding step for study of sulfur oxides and fly ash in the dispersed plume. (6) Collect and analyze sufficient plume samples to establish the relative proportions of SO_2 and SO_3. (7) Interpret and analyze data and observations. In steps 1 through 4, flue gas and fly ash samples were taken at ground level from the duct section connecting the mechanical fly ash collectors and the induced draft fan, or from the dilution chamber. APTIC #3777.

75. Gartrell, F. E., F. W. Thomas, S. B. Carpenter, F. Pooler, B. Turner, and J. M. Leavitt.
FULL SCALE STUDY OF DISPERSION OF STACK GASES. PART III. PLUME RISE. TVA, Chattanooga, Div. of Health and Safety and Public' Health Service, Cincinnati, Ohio, Div. of Air Pollution, June 1965, 34p.

This project was concerned primarily with investigation of diffusion rates in a steam plant smoke plume. While detailed data were obtained on plume rise at the time of each field sampling operation, the extensive observations required for a study designed specifically to improve procedures for estimating plume rise were not a part of the project. However, it is recognized that reasonably accurate estimates of plume rise under various operational and meteorological conditions are required for useful application of the derived diffusion parameters. The data which were obtained on plume rise concurrent with diffusion studies are, therefore, presented. Also, observed values are compared with calculated values and limited analysis is made of interrelations of plume rise with meteorological and diffusion parameters. A sufficient number of observations were not made for useful evaluation of the relations among plume rise, plume direction, and stack alignment. Data on plume rise were obtained only in inversion conditions and in neutral, moderately high wind velocity conditions. All observations relate to the Colbert Steam Plant, for which design and operational data are presented. APTIC #4035.

76. Gartrell, F. E., F. W. Thomas, S. B. Carpenter, F. Pooler, B. Turner, and J. M. Leavitt
FULL SCALE STUDY OF DISPERSION OF STACK GASES. PART II. DIFFUSION IN HIGH WIND NEUTRAL CONDITIONS. TVA, Chattanooga, Div. of Health and Safety and Public Health Service, Cincinnati, Ohio, Div. of Air Pollution, June 1965, 77p.

Field instrumentation and procedures for high wind neutral conditions were similar to those used in the study of dispersion during inversion conditions. However, the aerial sampling plan was modified to facilitate definition of the more mobile plume. In most instances replicate flights were made across the plume at successively lower elevations from top to bottom of the plume. Near the plant where the plume was relatively narrow, SO_2 distribution was determined in some instances by sampling along the plume centerline or x axis. Within a relatively short distance or travel time the plume was widely dispersed in both horizontal and vertical dimensions. This much larger plume section and attendant longer time required for sampling each section restricted maximum sampling concentration at this distance had diminished to such a low level that plume definition from recorder charts no longer was possible. APTIC #4034.

77. Gartrell, F. E., F. W. Thomas, S. B. Carpenter, F. Pooler, B. Turner, and J. M. Leavitt
FULL SCALE STUDY OF DISPERSION OF STACK GASES. PART I. DIFFUSION IN INVERSION CONDITIONS. TVA, Chattanooga, Div. of Health and Safety and Public Health Service, Cincinnati, Ohio, Div. of Air Pollution, June 1965, 148p.

Beginning at daybreak, or sometimes before daybreak on days when inversions were forecast meteorological data were logged each 30-minute period, and pibal observations were made each hour. A small light attached to the balloon permitted nighttime observations. To conserve manpower and to permit more frequent observations, theodolite readings were dictated into a recorder. At daybreak the Titrilog was transferred from car to helicopter, and it and other instruments were checked. Following takeoff, horizontal flights were made to check temperatures at the bottom and top of the meteorological tower. The vertical temperature profile was determined by a prescribed flight pattern where temperature readings were taken at 100-ft intervals starting at about 500 ft above the top of the plume. Plant personnel were alerted by an intercom system to begin special coal and SO_2 sampling at the approximate time that actual plume sampling was begun. Cross sections normally were begun at the 1/2-mile section and continued at progressively greater distance as time permitted before strong changes in thermal and wind structure occurred. Actual plume sampling time usually averaged about two hours. During this time cross sections were taken at about four selected distances downwind from the plant. In flight the observer recorded temperature and elevation data, marked the Titrilog chart for later identification of each plume transect and entered other pertinent observations on the chart or voice recorder. After completion of plume transects, temperature soundings were repeated before the flight was terminated. APTIC #4033.

78. Gifford, F., Jr.
RELATIVE ATMOSPHERIC DIFFUSION OF SMOKE PUFFS. J. Meteorol., 14:410-414; 475-476, Oct. 1957.

The spreading of smoke puffs in the atmosphere should be governed by the laws of relative diffusion that have been advanced by Brier (1950) and by Batchelor (1949-1956), and not by Taylor's fixed-source diffusion law (1920). The predicted mean-square puff spreading should proceed as time cubed, according to Batchelor's similarity theory of relative diffusion. Recent detailed smoke-puff measurements reported by Frenkiel and Katz (1956), and Kellogg (1956), make it possible to test the similarity theory of relative diffusion. Examination of these data indicates the existence of a time cubed spreading regime. Values of the rate of eddy-energy dissipation are also inferred from the smoke-puff data. APTIC #5701.

79. Gifford, F., Jr.
PEAK AVERAGE CONCENTRATION RATIOS ACCORDING TO A FLUCTUATING PLUME DISPERSION MODEL. Intern. J. Air Pollution, 3(4):253-260, 1960.

Short period concentration levels an order of magnitude greater than long period, average levels are frequently observed in the vicinity of isolated effluent sources. The dependence of the ratio peak to average concentration is established with the help of a fluctuating plume model of atmospheric dispersion. It is shown that this ratio approaches unity for large downwind distances (20 to 50 stack lengths) from an elevated source (stack). For samples obtained at considerable lateral or vertical distances from a plume, for example on the ground near a tall stack, the ratio may reach values of 50 to 100 or more. For samples on the mean plume axis, the ratio can be expected to be from 1 to about 5. These conclusions are in agreement with data on observed peak to average ratios obtained from a number of sources. APTIC #5700.

80. Gifford, F. A., Jr.
ATMOSPHERIC DISPERSION CALCULATIONS USING THE GENERALIZED GAUSSIAN PLUME MODEL. Nucl. Safety, 2(2):56-59, Dec. 1960.

Results of recent dispersion experiments have more and more often been presented in terms of the simple Gaussian interpolation formula. There is a practical need for a group of special formulas based on the Gaussian interpolation formula. From a review of previous literature, formulas are presented which consider a volume-source, fumigation, crosswinds, long period concentrations, maximum concentrations and their distances from the source, cloud width, cloud height, deposition, washout, and radioactive dosage. APTIC #5702.

81. Gifford, F. A., Jr., W. M. Culkowski and W. F. Hilsmeier
COMPUTATION OF ATMOSPHERIC DISPERSION PARAMETERS AT REACTOR SITES BY A SMOKE PLUME RATIO METHOD. Preprint. (Presented at the International Conference on Radioactive Pollution of Gaseous Media, Saclay, France, No. 1963.)

Estimation of atmospheric dispersion is one of the principal objectives of meteorological studies conducted at reactor sites, and it is often the most difficult one to achieve. Observations of smoke plumes have frequently been used effectively as a qualitative substitute for tracer experiments; these observations do give considerable insight into local diffusion patterns at reactor sites. Formulae previously obtained, for the determination of Sutton diffusion parameters from a simple measurement of smoke plume length-width ratios, have been summarized. Using these equations diffusion parameters at or near four U. S. Nuclear reactor installations have been determined; in each instance, the requisite plume length-width ratio information has been obtained from published photographs.
For several of the resulting estimates of diffusion parameters, an independent estimate based on actual measured air concentration measurements is available. The "observed" diffusion parameter values (i.e. those inferred from air concentration measurements) and the values predicted by the present method are in reasonable agreement, although the ratio method values are somewhat larger. The ratio method is distinguished by its simplicity and extreme economy. On the theoretical side, it is based on exactly the same diffusion models that are ordinarily employed in more elaborate reactor site diffusion studies.
The suggestion is that it should prove to be a useful, practical method by which to determine diffusion parameters at reactor sites, particularly sites, where either a large, permanent meteorological office is not contemplated, or where the expense of more elaborate atmospheric sampling studies of diffusion does not seem to be warranted. APTIC #6553.

82. Gifford, F. A., Jr.
ATMOSPHERIC TURBULENCE AND DIFFUSION. (Special Lecture IV).
In: Proc. of 2nd Southeastern Seminar on Thermal Sciences, July 25-26, 1966, Oak Ridge, Tenn., Hoffman, H. W. and Vachon, R. I. (eds.), pp. 147-171, 1966.

The character and properties of the lower atmosphere are summarized. The atmosphere is characterized by a very high turbulence level; approximately 50% turbulence levels are not uncommon. The Reynolds number in the atmosphere is difficult to specify; but if height above the ground is used as the length parameter in Reynolds number, the atmosphere is characterized by a very high Reynolds number. The assumption for theoretical purposes is that flows are horizontally homogeneous in their turbulence properties. The surface layer, or approximately constant stress layer, extends to 10 to 100 meters above the ground. It is characterized by values of friction velocity of roughly 15% or so of the mean wind at approximately 10 meters. The roughness length can be from 10^{-3} cm to perhaps 10 cm. Above the surface layer, the mean wind veers and increases, turning toward higher pressure with increasing height and attaining the free (i.e. nonturbulent) atmosphere value at elevations normally about several thousand feet in the atmosphere. Atmospheric turbulence is characterized by a quite large inertial subrange of eddy sizes; the dissipation scale is on the order of millimeters; and the integral scale, that is the upper end of this inertial range, must be at least 100 meters under most conditions. Regarding the Peclet number, bulk thermal convection strongly dominates the molecular temperature conduction. Richardson's number, which is the ratio of turbulent energy production by shear to consumption by buoyancy, is variable depending upon the nature of the stability in the lower atmosphere. APTIC #9760.

83. Gifford, F. and R. Waterfield
SIMPLIFIED ATMOSPHERIC DIFFUSION CALCULATIONS WITH SLIDE-RULE GAGE POINTS. In: Proc. of the USAEC Meteorological Information Meeting held at Chalk River Nuclear Laboratories, Sept. 11-14, 1967. Mawson, A. (Ed.)

Gage points are given with the help of which the most commonly required atmospheric diffusion calculations can be carried out rapidly using a simple slide-rule setting; e.g. maximum ground concentration, its distance, and the corresponding effective stack height as functions of the prevailing type of meteorological condition. APTIC #10052.

84. Gill, G. C., L. E. Olsson, J. Sela and M. Suda
ACCURACY OF WIND MEASUREMENTS ON TOWERS OR STACKS. Bull, Am. Meteorol. Soc., 48(9):665-674, Sept. 1967.

Wind sensors mounted on towers and smokestacks do not always indicate the true free-air flow. To determine the probable errors in measurement of wind speed and direction around such structures, quarter-scale models have been tested in a large wind tunnel. Data on changes in wind speed and direction were obtained by using smoke, very small wind vanes, and a scale model propeller anemometer. Most emphasis has been placed on a relatively open lattice-type tower, but a solid tower and a stack were also studied. The analysis shows that in the wake of lattice-type towers disturbance is moderate to severe, and that in the wake of solid towers and stacks there is extreme turbulence, with reversal of flow. Recommendations for locating wind sensors in the wind field relative to the supporting structure are given for each of the three structures studied. Guidelines are suggested regarding probable errors in measurements of wind speed and direction around different supporting structures, as outlined below. For an open triangular tower with equal sides D, the wake is about 1-1/2D in width for a distance downwind of at least 6D. Sensors mounted 2 D out from the corner of such a tower will usually measure speeds within + or - 10° of that of the undisturbed flow for an arc of about 330°. The disturbance by very dense towers and stacks is much greater. Wind sensors mounted 3 diameters out from the face of a stack will measure wind speeds within + or - 10%, and directions with + or - 10° of the undisturbed flow for an arc of about 180°. APTIC #7704.

85. Halitsky, J.
DIFFUSION OF VENTED GAS AROUND BUILDINGS. J. Air Pollution Control Assoc., 12(2):74-80, 1962.

Some fundamental aspects of flow and diffusion around sharp-edged buildings are described. The results of previous wind tunnel tests are generalized into formulae which may be useful for a rough approximation of concentrations produced by gas released from a flush vent. Details of the model tests are appended. APTIC #4607.

86. Halitsky, J.
A METHOD FOR ESTIMATING CONCENTRATIONS IN TRANSVERSE JET PLUMES.
Intern. J. Air Water Pollution, 10(11-12):821-843, Dec. 1966.

Gas released from a chimney or a flush vent diffuses initially in a transverse jet and then forms a simple plume as jet velocities decay to the ambient wind condition. A number of formulae have been offered by calculating concentrations in the simple plume region; these generally ignore initial diffusion or compensate for its effect by assuming that the gas is released from a virtual point source upwind of the stack. Experimentally verified methods for calculating concentrations in the transverse jet region and for estimating the location of the virtual source have not appeared in the literature. In this paper the available data on transverse jets have been assembled and fitted into a simple mathematical diffusion model. The matching of the transverse jet plume leads to a rational method for estimating the virtual source location. Since all of the test data were obtained in low-turbulence wind tunnels, the empirical expressions selected to fit the data are not strictly applicable to jets in a natural wind; therefore the model should be considered as a first approximation, to be modified as field data become available. Isothermal conditions are assumed, but it is thought that the major change to be expected for heated jets is in the curvature of the plume centerline, a subject which is not treated in detail in this presentation. The model provides for an extension of the plume beyond the transverse jet region, either by the conventional diffusion formulae if the characteristics of the wind stream are known to be homogeneous as in an unobstructed flow over level ground, or by the use of two experimental constants related to the mean wind velocity and average turbulence in the plume path for chaotic flow fields such as exist in building wakes. Numerical values of these constants for a few configurations are determined by applying the model to the test data. Suggestions are determined by applying the model to the test data. Suggestions are offered for the selection of appropriate constants in calculating concentrations near buildings. APTIC #2857.

87. Haltisky, J., G. Magony and P. Halpern.
TURBULENCE DUE TO TOPOGRAPHIC EFFECTS. (Second Semi-Annual (Final) Rept. Jan. 1, 1965 to June 30, 1965), New York Univ., University Heights, Bronx, N. Y. School of Engineering and Science. (Geophysical Science Lab. Rept. No. TR 66-5), 1966.

The purpose was to investigate air flow in the lee of a topographical obstruction by making wind tunnel measurements near a model of a specific mountain ridge and comparing them with available full-scale measurements near the prototype ridge. Wind tunnel tests were undertaken to explore Reynolds Number and background flow turbulence effects on the flow field in the lee of a mountain ridge oriented normal to the air stream. Three types of tunnel air streams were used. The results were compared among themselves and with the results of full-scale pilot balloon observations over the prototype of the model ridge, reported by

Davisson (1963). It was found that with a low turbulence background flow and Reynolds Number of about 10^5 based on peak height above valley floor the characteristics of the full scale field below ridge line height were fairly well reproduced, both qualitatively and quantitatively, despite different measurement techniques. A Reynolds Number of about 10^4 was found to exaggerate the influence of viscosity. The principal effect of high background flow turbulence was to mask the extent of wake penetration upward and effectively shrink the wake dimensions both vertically and laterally. Periodic wake flow breakdowns in the high turbulence condition were attributed to long-period oscillations in the tunnel air stream, and this suggested an explanation for certain phenomena observed in full scale. APTIC #4291.

88. Halitsky, J.
COMMENT ON WIND TUNNEL SIMULATION OF LARGE-SCALE HORIZONTAL WIND OSCILLATIONS. Atmospheric Environ., 1: (5) 607-608, 1967.

The difficulties encountered in studying the long-period horizontal fluctuations of the wind on diffusion near a building by use of a proposed model in a wind tunnel are discussed. The simulation could be accomplished by using a steady wind and oscillating a model of the building on a turntable according to a magnetic tape record of an atmospheric wind. This technique would introduce spurious velocities which would affect the diffusion pattern near the building. The extent of the distortion has not been determined. The spurious velocities arise from the tangential velocity points located a distance from the center of rotation of the turntable. When combined with the uniform tunnel airstream velocity, the tangential velocities produce a varying resultant local velocity, relative to the model. There is no counterpart to this effect in the full-scale condition. Experiments have demonstrated the sensitivity of diffusion patterns near buildings to orientation to the mean wind therefore, there is reason to suspect that the varying relative orientation produced by turntable angular velocity may prove significant. Diffusion experiments on chimney jets in a tunnel airstream that is oscillated by means of vanes at a design frequency of about 0.3 c/s, with provision for reducing the frequency still further are being conducted. The intention here is to study the behavior of the jet in a turbulent tunnel wind whose dominant frequency corresponds to that found at chimney height in a full-scale atmosphere. Measurements taken with a non-turbulent wind in the manner described previously are to be integrated for comparison with measurements in the turbulent wind. APTIC #6546.

89. Hamilton, P. M.
PLUME HEIGHT MEASUREMENTS AT TWO POWER STATIONS. Atmospheric Environ., 4(1): 379-87, July 1967.

The Northfleet plume was studied by means of a lidar technique. The lidar was located 2.7 km from the stack on a bearing of 067. Most of the measurements were made with the plume blowing from between 200 and 240. The lidar was aimed in such a direction that it intercepted the plume at the desired distance from the source. The plume was then scanned at a series of up to 11 angles of elevation. Since the lidar could only be fired at intervals of about 15 sec, a complete scan required up to 3 min. When the scan had been completed, the positions of the lidar echoes were plotted on a vertical section. It was then usually possible to identify the Northfleet plume and draw its envelope. From this measurements of the mean height of the plume and its vertical and horizontal dimensions were made. The principal factor affecting plume rise is wind speed. All the measurements were made at a distance betwen 1200 and 2500m from the source with most of them near 1800m. They were made in a variety of meteorological conditions, mostly in April and May 1966. APTIC #1932.

90. Hauser, W.
SMOKE-DISPERSING STACK TOPS, LATTICE STACKS AND INJECTOR STACKS FROM A THEORETICAL POINT OF VIEW. Turbulenzaufsatze, Gitterschornsteine in Theoretischer Sicht. Angew, Meteorol. (Berlin) 5: (Special Issue) 20-7 Ger. 1965.

Assuming the applicability of the Sutton diffusion formula and using the Stumke plume rise formula, an estimation is made of a practicable decrease of emission of gaseous air pollution obtainable by various methods such as smoke-dispersing stack tops, lattice-type stacks with air ports, and injector stacks. None of the methods is completely satisfactory; smoke-dispersing stack tops cause a decrease of gaseous air pollution emission only in the immediate vicinity of the stack; lattice-stacks cause a rise in the air pollution in the regions of maximum emission and injector stacks are successful only with cold smoke. APTIC #0409.

91. Hebley, H. F.
ATMOSPHERIC POLLUTION CAUSED BY THE DIFFUSION OF WASTE INDUSTRIAL GASES. Proc. Nat'l. Air Pollution Symp., 1st., Pasadena, Calif., pp. 97-102, 1949.

The various influences that control the natural dissipation of airborne industrial wastes are considered. Geographic location and topography play a major role in the fate of airborne pollutants, and these factors are highlighted in a table showing areas of the U. S. having pollution problems, along with the dominant industry in each area. Examples of the combined effects of topography and meteorology are given for the Pittsburgh area. Also discussed are the physical location of stacks and their height in relation to pollution. APTIC #4978.

92. Hewson, E. W. and L. E. Olsson
LAKE EFFECTS ON AIR POLLUTION DISPERSION. J. Air Pollution Control Assoc., 17(11): 757-761, Nov. 1967.

Local wind regimes induced by a lake or a shoreline may have a major influence on air pollution dispersion. Pressure differences due to differential heating of the air, e.g., that due to differences in surface characteristics, are the driving forces of lake and land breeze circulations and slope and valley winds. Differences in roughness between land and lake surfaces will cause wind shear and aerodynamic downwash effects at a shoreline. Stability changes in the air result from differences in surface temperature and roughness between land and lake, e.g., when warm unstable air moves out over a cool lake a temperature inversion will develop near the surface giving very poor dispersion conditions in this lower layer. Pollution released in this stable layer may be carried in high concentrations for many miles and cause severe damage as the air moves across a downwind shoreline and advances inland. The information presented is designed to permit an assessment of the probable complexity of the dispersion patterns near a shoreline so that possible requirements for additional meteorological and dispersion information may be determined. Brief descriptions of two actual lakeside sites, one on Lake Erie and the other on Lake Michigan, are given and their relevant characteristics are presented. Natural ventilation was above average at both sites. APTIC #7872.

93. High, D. and W. H. Megonnell
DEVELOPMENT OF REGULATIONS FOR SULFUR OXIDE EMISSIONS. Preprint, Public Health Service, Wash., D. C., NCAPC. 1968.

On the basis of Executive Order No. 11282, which requires that all Federal agencies take steps to prevent and control air pollution from their installations, a study of the regulation of sulfur oxide emissions from Federal facilities is reported. Community air quality goals, current pollution concentrations and pollution sources, reduction necessary to meet air quality goals, considerations of stack heights, suggestions for resolving the sulfur oxides problem from Federal facilities and conclusions and recommendations are discussed. APTIC #10146.

94. Hilst, G. R. and N. E. Bowne
A STUDY OF THE DIFFUSION OF AEROSOLS RELEASED FROM AERIAL LINE SOURCES UPWIND OF AN URBAN COMPLEX. Final Report. Travelers Research Center, Inc., Hartford, Conn. Vol. 1, July, 229 pp. 1966.

The data obtained during 70 separate experimental measurements at Fort Wayne, Indiana are tabulated. Included are: Surface Rotorod Dosage Printout; Ten-station Means and Standard Deviations; Filter Sampler Surface Dosages; Vertical Array Rotorod Dosages; Climet Direction, Speed, and Turbulence Intensity; Surface Vector Vane Data; Tower Vector Vane Data; Vertical Velocity Spectra: Pilot Balloon Observations; Surface Temperature Data; Tower Temperature Data; Radiosonde and Wiresonde Data; Tracer Arrival Times; and Airways Observations. APTIC #7983.

95. Hoult, D. P., J. A. Fay, and L. J. Forney
A THEORY OF PLUME RISE COMPARED WITH FIELD OBSERVATIONS. Preprint. (Presented at the 61st Annual Meeting, Air Pollution Control Assoc., St. Paul, Minn., June 23-27, 1968.)

A theory for the rise of a plume in a horizontal wind is proposed in which it is assumed that, for some distance downwind of a high stack, the effects of atmospheric turbulence may be ignored in comparison with the effects of turbulence generated by the plume. The theory, an extension of the local similarity ideas used by

Morton, Taylor and Turner, has two empirical parameters which measure the rate surrounding fluid is entrained into the plume. Laboratory measurements of buoyant plume motion in laminar unstratified cross flow are used to evaluate the empirical parameters. Using this determination of the parameters in the theory, the trajectories of atmospheric plumes may be predicted. To make such a prediction, the observed wind velocity and temperature as functions of altitude, and flow conditions at the stack orifice, are used in numerically integrating the equations.

The resulting trajectories are compared with photographs of plumes from 500 to 600 ft. high stacks made by Leavitt et al of TVA. Within 10 stack heights downwind of the stack, the root mean square discrepancy between the observed height of the trajectory above ground level and the theoretical value is 14%, which is about the uncertainty in the observed height. The maximum plume rise within the field of observation is compared with empirical effective stack height formulae and with the present theory, and is found to be closer to the latter.

96. Islitzer, N. F.
SHORT-RANGE ATMOSPHERIC-DISPERSION MEASUREMENTS FROM AN ELEVATED SOURCE. J. Meteorol., 18(4): 443-450, Aug. 1961.

Dispersion measurements of a tracer, uranine dye in solution, were made out to two miles from the release point in unstable atmospheres. The tracer was released from the top of a 150-ft tower and sampled at ground level by 100 high volume air samplers. Some sixteen releases for 30-min periods were analyzed. Techniques of dispersal, collection and analysis of the tracer are included. Meteorological measurements during the tests included vertical- and horizontal-wind-direction variances predicted from a meteorological model using wind-direction variances as dispersion parameters. Prediction equations are also empirically developed for computing the distance to maximum ground-level air concentration and for lateral particle variance to two miles. The measured vertical inhomogeneity of turbulence does not prevent a fair agreement between predicted and measured surface air concentrations when only source-height wind data are used. Since the dispersion parameters were determined at the time of the diffusion experiments, the observed and computed results are not independent. Independent test data were not available for a more rigorous check of the method. APTIC #5716.

97. Islitzer, N. F. and R. K. Dumbauld
ATMOSPHERIC DIFFUSION - DEPOSITION STUDIES OVER FLAT TERRAIN. Intern. J. Air Water Pollution, 7: 999-1022, 1963.

Extensive measurements of particle dispersion from a ground-level source to 3.2 km were carried out covering a wide range of atmospheric stabilities. Uranine dye was released for 60-min periods over a grid 60° wide with sampling arcs operated out to 3200 m downwind. An additional series of tracer releases were conducted with sampling near the ground to 800 m downwind and in the vertical direction on 30-m towers located 200 or 400 m downwind. Measurements of the vertical temperature gradient, wind velocities and gustiness were made near the tracer-release point. The horizontal particle dispersion was found to be well predicted in unstable atmospheres by the standard deviation of the horizontal wind direction after averaging the wind direction record by a time dependent upon the travel time from the source to the particular sampling arc. Vertical dispersion, as computed from ground-level air concentration and the equation of continuity, was not in good agreement with predictions from time-average vertical wind direction record. The vertical dispersion determined from the air concentration measurements on the towers at one distance was found to be in reasonable agreement with vertical gustiness data. Up to a 50 per cent loss of tracer due to deposition in a distance of 400 m was measured. Air concentrations measured in unstable atmospheres were in good agreement with values predicted from a model employing horizontal and vertical gustiness and a deposition velocity to account for the removal of tracer from the air to the ground. The agreement between predicted and measured values was less satisfactory for inversion cases. APTIC #5715.

98. Katz, E. J.
ATMOSPHERIC DIFFUSION OF SETTLING PARTICLES WITH SLUGGISH RESPONSE. J. Atmospheric Sci., 23: 159-166, Mar. 1966.

A study is presented of the settling of heavy particles in a turbulent medium and quantitatively applied to the lower atmosphere. The response time of settling particles to changes in the velocity of their surroundings is estimated for a wide range of particle sizes and this time is then compared to the period during which such changes may be expected to occur during settling. The reduction in diffusion due to insufficient response time is predicted. If the time of fallout is sufficiently large compared to the particle's response time, no significant reduction is effected, as had been previously suggested. An attempt is included to numerically predict the diffusion of settling particles. APTIC #1239.

99. Khorguani, V. G.
THE CHARACTER AND SETTLING VELOCITY FOR A SYSTEM OF EQUAL-SIZED PARTICLES. Atmospheric and Oceanic Physics, 2(4): 234-238, Apr. 1966.

Investigation of the patterns of motion of particle system is of interest in relation to the formation of precipitation and the spread and rate of settling of various industrial aerosols, etc. An experimental study was made of the character and rate of fall of particles of equal size in an isolated hydrodynamic system. It was shown that the settling velocity at which a system of equal sized particles moves under the influence of gravity is higher than that of an isolated particle. The velocity at which a particle system moves is inversely proportional to the Reynolds numbers. If the initial distance between the particles is more than 30-53 diameters there will be no increase in velocity of the system. APTIC #2114.

100. Kuhme, H.
INVESTIGATIONS ON SO_2 DIFFUSION IN THE VICINITY OF A POINT SOURCE.
STAUB (English Transl.), 26(3): 29-32, Mar. 1966.

Measurements carried out in the region of an isolated chimney have shown that, as has been frequently assumed, essentially higher diffusion coefficients must be introduced in the distribution formula to obtain sufficiently accurate description of the waste gas distribution. APTIC #2692.

101. Laikhtman (Leichtmann), D. L., F. A. Gicina, and N. I. Kramer
TAKING THE SPECIAL FEATURES OF ATMOSPHERIC TURBULENCE INTO ACCOUNT WHEN CALCULATING THE POWER AND HEIGHT OF SMOKESTACKS OF INDUSTRIAL PLANTS. Atmospheric and Oceanic Physics (English Transl.), 1(11): 705-707, Nov. 1965. Russ. (Tr.)

The calculation of the permissible smokestack height H should be based on an assessment of the probability of the realization of various meteorological situations. Maximum ground concentration (gm) for fixed external conditions is calculated according to well known formulas (taking small-scale turbulence into account), while the repeatability of various values of q_m is found on the basis of statistical data concerning a set of values of meteorological conditions (taking large vortices into account). The parameters of the plant being designed should be chosen in such a way that the maximum ground concentration in the direction of greatest repeatability of the wind will, with a certain probability, not exceed the maximum permissible. A mathematical solution to this problem is the main purpose of this article. An equation is derived which for a given probability that the maximum concentration will not exceed the maximum permissible, any of the desired parameters of the smokestacks of an industrial plant can be determined. APTIC #5730.

102. Lucas, D. H., D. J. Moore, and G. Spurr,
THE RISE OF HOT PLUMES FROM CHIMNEYS. Intern. J. Air Water Pollution. 7:473-500, 1963.

Measurements of plume rise at two Central Electricity Generating Board power stations have led to the formula alphaQl/4/U where alpha is 4900 for one station and 6200 for the other. (U = wind speed in ft/sec; Q = heat emission in MW Z_{max} = plume rise in ft.) A number of other publications of measured results have been considered and shown to be in reasonable agreement with the formula, provided a correction is applied for the distance at which maximum plume height is measured. The results do not agree with any previously published theoretical formula, but the theory of Priestley has been considered and is shown to be capable of reconciliation with the measured results. It is shown that measured results of plume rise can be reconciled with measured results of ground-level concentration, provided there is a proper discussion of the relationship between short-term and long-term measurements. Further study is needed to establish the reasons for the variations in the experimental values of alpha. APTIC #3557.

103. Lucas, D. H., K. W. James, and I. Davies
THE MEASUREMENT OF PLUME RISE AND DISPERSION AT TILBURY POWER STATION. Atmospheric Environment, 1(4):353-365, July 1967.

A description is given of the system of instrumentation which has been installed at Tilbury Power Station to record continuously: (a) surface sulphur dioxide concentration at distances from 1 km to 13 km downwind of a 360 MW power station with two 100m stacks; (b) the rise of the plume; (c) lapse rate, humidity, turbulence, wind speed and wind direction up to 187 m above ground level. The paper is intended as a common introduction to a number of papers which will present the experimental results. APTIC #1684.

104. Lucas, D. H. and W. L. Snowsill
SOME DEVELOPMENTS IN DUST POLLUTION MEASUREMENT. Atmospheric Environment, 1(6):619-636, Nov. 1967.

Instruments for the continuous measurement of dust emitted from industrial chimneys are reviewed. These include: 1) Optical density type instruments; 2) light scattering instruments; 3) AEI dust sampling instrument; 4) the konitest; 5) the standard CERL flue dust monitor; and 6) the simplified CERL flue dust monitor. The first four instruments are more sensitive to fine dust and the latter two more sensitive to coarse dust. The measurement of dust emission is considered in relation to public complaint. At least two measurements are required -- ideally these should be dust amount and dust grading. No viable instruments exist to measure dust amount or dust grading continuously, and in practice it is best to use an instrument to record the optical density of the flue gas and a C.E.R.L. dust monitor. These monitor directly the two main causes of complaint. They also give warning of certain forms of inefficiency in combustion. In addition the comparison of their readings is a useful indication of dust coarseness. APTIC #8856.

105. Mahler, E. A. J.
STANDARDS OF EMISSION UNDER THE ALKALI ACT. Proc. (Part I) Intern. Clean Air Cong., London, 1966, pp. 73-76.

The evolution of standards of emission under the Alkali Act over the past 100 years is briefly reviewed. The necessity for considering heights of discharge of pollutants as well as their concentration in the emissions and mass rates of discharge to atmosphere is stressed. It is also indicated that standards should be simply and clearly expressed in such a manner that their due observance can readily be checked by short and simple tests. An outline is given of the principles adopted in arriving at the current standards and these, both in regard to concentrations in emissions and heights of discharge, are listed. The author expresses the personal view that present tendencies in ever increasing size of production units and complexity of operations on one site must inevitably lead to necessity in the future further to reduce emissions. Because of the cost of such a step he suggests that setting up and adoption of international standards is a desirable end. APTIC #2010.

106. Martin, A. E.
REPORT ON CHIMNEY EMISSIONS (FIDDLER'S FERRY POWER STATION).
Central Electricity Generating Board, England, June 1966, 19p.

Prevailing levels of atmospheric pollution in St. Helens, Warrington and Widnes are high and the available evidence indicates that the incidence and mortality from bronchitis is also high. Atmospheric pollution is known to be an important contributing factor influencing both the number of cases and of deaths from this disease. Any proposal which might contribute towards an increased level of air pollution in the district must therefore be examined with great care. From the height at which the fumes from the proposed power station would be discharged and from the known behaviour of chimney emissions under varying weather conditions, the evidence indicates that the power station would make but a tiny contribution to the prevailing ground level concentration of sulphur dioxide. Moreover, the sulphur dioxide pollution from the power station would be of a transient nature and would only affect the surrounding area at a time when the natural ventilation is good and ground pollution from local sources is low. At times when owing to climatic conditions pollution from local sources is high fumes from the power station would not descend to ground level within this area. APTIC #2416.

107. Martin, A. and F. R. Barber
SULPHUR DIOXIDE CONCENTRATIONS MEASURED AT VARIOUS DISTANCES FROM A MODERN POWER STATION. Atmospheric Environ., 1(6):655-677, Nov. 1967.

Data are presented on ground-level concentrations of sulphur dioxide measured at various distances from High Marnham Power Station during the period October 1965 to September 1966. The measurements include pollution from background sources around the area, as well as from the Power Station, and the results are compared with those of previous years. As before, most of the pollution arrived from the west during fumigations, probably from distant urban sources. The pollution in the area has decreased steadily since 1963, especially in stable conditions in winter, but this decrease is due, in part, to the decrease in the frequency of persistent fog situations over the same period. Short-term pollution from High Marnham alone was occasionally detected at sites between 1/2 and 17 mi (0.8 to 28 km) from the source. The details given extend those published previously. Information is given on concentrations recorded near the source in the summer, and on possible additive effects of power station contributions. APTIC #8858.

108. Martin, J. E.
THE CORRELATION OF WIND TUNNEL AND FIELD MEASUREMENTS OF GAS DIFFUSION USING KRYPTON-85 AS A TRACER (A DOCTOR'S THESIS).
(For the degree of Doctor of Philosophy, Michigan Univ.) 1965, 141p

In order to determine the reliability of wind tunnel tests in predicting diffusion at a site where theoretical models are inapplicable, namely at the Ford Nuclear Reactor at the University of Michigan, diffusion was measured to realize the following objectives: (1) to determine in the field the degree of dilution between the stack and various ground-level locations using a radioactive tracer for various combinations of wind speed, wind direction, and atmospheric stability; (2) to repeat dilution determinations with a scale model of the site in a wind tunnel with atmospheric stability restricted to the neutral conditions of the tunnel air; (3) to correlate the two sets of data to determine the reliability of wind tunnel tests in predicting full-scale diffusion at the site; and (4) to compare the wind tunnel prediction with theoretical predictions for the site to show the relative value of each. Wind tunnel measurements of concentrations correlated directly, within experimental error, with average field concentrations in the cavity of the reactor building that released gases from short stacks. Outside the cavity, wind tunnel measurements of concentrations correlated directly, within experimental error, with peak concentrations observed in the field. The correlation of field data and wind tunnel data were independent of atmospheric stability conditions because of the dominance of aerodynamic influences on the plumes. Wind tunnel measurements which predicted peak values could be used to determine average concentrations by considering peak-to-mean ratios of concentration as a function of the horizontal gustiness. Wind tunnel measurements gave a better estimate of diffusion for the site, which had uneven terrain and buildings near the source, than the Sutton model. Field confirmations of the wind tunnel data showed that the modeling and scaling criteria used were representative of the full-scale phenomena. Krypton-85 is a versatile tracer for field studies and wind tunnel studies of the dilution of stack gases. APTIC #4353.

109. Meyer, Erich
RELATION OF AIR POLLUTION TO LOCAL GROUND LEVEL SO_2 CONCENTRATION. A SUGGESTION FOR AN IMPROVED CALCULATION OF POLLUTANT DISTRIBUTION. [Zusammenhang zwischen Immission und Grundbelastung der Atmosphäre. Ein Vorschlag zu einem verbesserten Verfahren der Ausbreitungsrechnung.] Text in German. Brennstoff-Waerme-Kraft (Dusseldorf), 19(9):443-445, Sept. 1967.

Present calculations of minimal stack heights for the prevention of excessive SO_2 ground level concentrations based on emissions in a single smoke plume, are shown to be inadequate. A new method of calculation is presented, using an increased radius (5km.) of distance from the stack, and utilizing the concepts of wind velocity frequency and wind direction frequency. The advantages and limitations of the method are discussed. APTIC #8593.

110. Montgomery, T. L. and M. Corn.
ADHERENCE OF SULFUR DIOXIDE CONCENTRATIONS IN THE VICINITY OF A STEAM PLANT TO PLUME DISPERSION MODELS. J. Air Pollution Control Assoc., 17(8):512-517, Aug. 1967.

Air monitoring data for a calendar year at one of the TVA power plants has been used to evaluate the appropriateness of the Sutton, the Bosanquet and Pearson, and the USPHS-TVA atmospheric dispersion models to predict ground level concentrations of sulfur dioxide from emission and meteorological data. Aerometric data included one half hourly average sulfur dioxide concentrations, recorded by four Thomas autometers, and the necessary meteorological parameters for the solving of atmospheric dispersion models. Based on these meteorological parameters and observed plume rise data, over four thousand one half hourly average maximum and minimum expected ground line sulfur dioxide concentrations were predicted for each of the above dispersion models by the use of computer techniques. The plant is a line source; however, an empirical correction was applied to emission data to reduce them to emissions for an equivlent point source. The predicted sulfur dixoide levels for each of the dispersion models were compared to the measured levels throughout the year. Three different sets of diffusion coefficients were applied to the Sutton model and successful predictions, according to a criterion utilizing an acceptable range of concentrations, varied from 66 to 93%. The Bosanquet and Pearson model produced successful predictions 90% of the time, while the USPHS-TVA model was successful 94% of the time. Unsuccessful predictions were primarily overestimates. APTIC #6414.

111. Moore, D. J.
METEOROLOGICAL MEASUREMENTS IN THE FIRST 600 FEET OF THE ATMOSPHERE. Central Electricity Research Labs., Leatherhead, England, 21p. (Presented at the Symposium on Chimney Plume Rise and Dispersion, Oct. 7, 1966.)

The plume measurements indicate that the medium scale turbulence at 187 m is mainly convective in origin, with the inference that in the absence of convection mechanical turbulence is largely suppressed at this level. The presence of a stable layer above a turbulence layer causes a marked decrease in turbulence with height. It is shown that care must be taken when temperature increases are observed over short height intervals (approximately 30 m) that these are not classified as stable layers when in fact they are due to organized convective currents affecting some levels on the tower. APTIC #1931.

112. Moore, D. J.
PHYSICAL ASPECTS OF PLUME MODELS. Intern. J. Air Water Pollution, 10:411-417, July 1966.

Visual observations of smoke plumes indicate that when the air at the stack top is turbulent the plume consists of a series of more or less separate puffs rather than a continuous cone of smoke. Such plumes will have a finite height of rise in a neutral atmosphere and so no artificial mathematical assumptions are required to produce a bounded plume height. Consideration of the magnitude of the various parameters likely to affect the final height indicates that the initial size and subsequent behaviour of the puffs is at least as important as the other variables (rate of heat emission, intensity of turbulence, efflux velocity and lapse rate) which are considered in earlier theoretical treatments. APTIC #1511.

113. Moore, D. J.
METEOROLOGICAL MEASUREMENTS ON A 187 METRE TOWER. Atmospheric Environ., 1(4):367-377, July 1967.

Measurements of temperature, humidity, turbulence, wind speed and direction on a 187 m high tower are described. The measurements indicate that the significant medium scale turbulence at 187 m is mainly convective in origin. In a stable layer above a turbulent layer, there is a rapid decrease in turbulence with height. Care must be taken when temperature increases are observed over short height intervals (approximately 30M) that these are not classified as stable layers when in fact they are due to organized convective currents affecting some levels on the tower. APTIC #8251.

114. Moore, D. J.
VARIATION OF TURBULENCE WITH HEIGHT. Atmospheric Environ., 1(4):521-522, 1967.

Values of intensity of turbulence sampled over 1 hr. and averaged over 30 sec. according to Pasquill (1967) are compared with the values given by Moore (1967) for 38 m, 114 m and 187 m on occasions when the Tilbury Power Station plume was reaching the ground. Some data are given by Munn (1965) for 25 m and a sampling period of 500 sec. Measurements at the different heights are compared in a table. The measurements indicate that in the absence of a stable layer below the measuring point, the low frequency vertical turbulence intensities tend to vary inversely as the wind speed at heights from 100 m upwards in winds below 10 msec $^{-1}$. In strong winds (greater than 10 msec^{-1}), the turbulence decreases monotonically with height and at 300 m and above root mean square vertical velocities are lower than they are in light winds while below 150 m they are higher in strong winds. This would seem to indicate that convective turbulence predominates at all wind speeds above 150 m, but strong winds tend to reduce the penetration of convective turbulence to layers at and above 300 m, if the small number of strong wind data at these heights are representative of the turbulence in these conditions. APTIC #8550.

115. Moore, D. J. and P. M. Hamilton
SOME APPLICATIONS OF LASERS IN ATMOSPHERIC STUDIES. Atmospheric Environ., 1(3):341-344, May 1967.

The interests described by the representatives of eleven groups (ten in the United Kingdom) are are using, or proposing to use, lasers to study the atmosphere are briefly summarized. These representatives are: R. T. H. Collis (Stanford Research Institute); L. G. Bird (Meteorological Office); C. Spraggs (R.A.E., Aberporth); M. C. W. Sandford (Radio and Space Research Station, Slough); K. Marsh (British Petroleum); D. E. Killick (Radio Dept., R.A.E., Farnborough); S. R. Craxford (Warren Spring Laboratory); W. R. Lane (C.D.E.E., Porton); P. M. Hamilton (Central Electricity Research Laboratories, Leatherhead); P. J. Bateman (Ministry of Aviation, R.A.E., Farnborough); and C. A. Small (Trinity House). APTIC #7447.

116. Moses, H. and G. H. Strom.
A COMPARISON OF OBSERVED PLUME RISES WITH VALUES OBTAINED FROM WELL-KNOWN FORMULAS. J. Air Pollution Control Assoc., 11(10): 455-466, Oct. 1961.

The height to which a stack effluent will rise in the atmosphere is of importance in calculating the resulting concentrations at ground level. There are at least eight theoretical or empirical formulas one may use, but these yields results which may differ by as much as an order of magnitude. A comparison of the predictions of six such formulas with data obtained with an experimental stack operated by the Meteorology Group at the Argonne National Laboratory was presented. The formulas tested are those of: (1) Holland, (2) Davidson and Bryant, (3) Sutton, (4) Scorer, (5) Bosanquet, Carey, and Halton, and (6) an additional one by Bosanquet. There is no one formula which is outstanding in all respects, but a suitable formula for calculating the height of plume rise may be selected. The nature of the problem would influence the selection of the formula. APTIC #5618.

117. Moses, H., G. H. Strom, and J. E. Carson
STACK PLUME RISE DETERMINATIONS AS AFFECTED BY METEOROLOGICAL AND ENGINEERING FACTORS. In: Radiological Physics Division Annual Report - July 1963 through June 1964. Argonne National Lab., Illinois, 1964, pp. 209-241. (Rept. No. ANL-6938)

The Davidson-Bryant, Holland, and Bosanquet formulas for the calculation of plume rise are discussed in detail and then used to determine the plume rise from the Argonne Experimental Meteorology Stacks. Data were previously obtained at the stack site by means of photogrammetric techniques. The calculated results are compared to the observed plume rise heights. Holland's formula with a correction factor of about 3 for large stacks and 2 for small stacks appears to be best. The effect of stability on the plume rise can be accounted for by adding 10 to 20% of the computed value for lapse conditions and subtracting the same amount for inversions. Irregular terrain, surrounding buildings, rain, wind gusts, and shape of stack can produce wide deviations in the calculated height. APTIC #6472.

118. Moses, H., G. H. Strom, and J. E. Carson
EFFECTS OF METEOROLOGICAL AND ENGINEERING FACTORS ON STACK PLUME RISE. Nucl. Safety, 6(1):1-19, 1964.

Field measurements of plume rise are extremely difficult to make. In spite of the lack of adequate measurements and satisfactory theory, practical problems arise that require decisions concerning the selection of a minimum stack height so that threshold values of atmospheric contaminants are not exceeded. Two of the most widely used empirical formulas, those of Davidson-Bryant and of Holland, and the semitheoretical formula of Bosanquet, are discussed in detail. The latter has been selected for study because it presumably represents an improvement over the widely used formula of Bosanquet, Carey, and Halton. A critical examination of the three formulas indicates that none is as good as might be hoped. Terrain effects, such as nearby buildings, hills, valleys, and forested areas, must be taken into account. In most cases this can only be done by wind-tunnel tests. Further, meteorological conditions may materially affect plume rise. No one formula can or should be expected to provide acceptable results under all conditions. APTIC #9413.

119. Moses, H. and J. E. Carson
STACK DESIGN PARAMETERS INFLUENCING PLUME RISE. In: Radiological Physics Division Annual Report. (July 1966 through June 1967). Argonne National Lab., Argonne, Ill., p. 169-173, 1967. Rept. No. ANL-7360.

A regression study relating plume rise with stack and meteorological variables was made using a fairly comprehensive set of data. Ten stacks were used, with plume rises and heat emission rates ranging over about three and four orders of magnitude respectively. A total of 710 individual observations were used. Two sets of measurements from the Argonne Meteorology Stack, three from industrial stacks in England, two stacks from Germany, and three stacks of the TVA complex were the source of data. There was appreciable nonuniformity among the data from the ten stacks. From the standpoint of goodness of fit and ease of computation, a plume rise equation is suggested. APTIC #9449.

120. Munn, R. E. and A. F. W. Cole
TURBULENCE AND DIFFUSION IN THE WAKE OF A BUILDING. Atmospheric Environ., 1(1):33-43, 1967. (Presented at the 58th Annual Meeting, Air Pollution Control Association, Toronto, Canada, June 20-24, 1965.)

The effect on a smoke plume of atmospheric turbulence in the lee of a building was examined by using a fluorescent dye as tracer. The plume centreline for each of a number of trials was established from measurements of a series of ground-level samples taken for that trial. Dilution rates were related to meteorological factors such as the mean wind and the turbulence (measured by bidirectional vanes) in advance and to the rear of the building. Finally, several formulae were tested for calculating the diffusion in the wake of an obstacle. APTIC #0732.

121. Plato, P. A., D. F. Menker, and M. Dauer
COMPUTER MODEL FOR THE PREDICTION OF THE DISPERSION OF AIRBORNE RADIOACTIVE POLLUTANTS. Health Phys., 13(10):1105-1115, Oct. 1967.

Presented are two computer programs written for an IBM 1401/7040 digital computer in a FORTRAN IV computer language. The programs are called RADS and ARADS, acronyms for Radiological Atmospheric Dispersion Study and Alternate RADS, respectively. Both programs are designed to investigate the use of various equations formulated to predict the dispersion of radioactive effluents deposited into the atmosphere from a smoke-stack. The release of the effluents may be of either an instantaneous or continuous nature. Predictions of atmospheric concentrations are made for approximately 600 points throughout an observation area surround the smoke source, allowing contour lines of equal concentrations to be drawn. The RADS program was designed for one particular effluent release. The program predicts the path of the smoke from the source to one of the boundaries of the observation area. Predictions are then made concerning the dispersion of the smoke. The ARADS program uses average meteorological conditions to predict the air concentrations resulting from long-term releases of a smokestack effluent. The output data for both programs contain a scaled map of the observation area showing the location of the predicted concentrations in order to simplify the drawing of the contour lines. While the authenticity of the prediction equations is not certain, a definite relationship between relative air concentrations with respect to the location of the source was established. The programs permit fast, accurate, and voluminous solutions to the complex equations, and provide a tool to examine the prediction equations themselves. APTIC #8539.

122. Santomauro, L.
(THE CURRENT STATE OF MATHEMATICAL MODELS FOR SINGLE ELEVATED SOURCES.) STATE ATTUALE DEI MODELLI MATEMATICI DELLE SORGENTI ELEVATE UNICHE. Fumi Polveri (Milan), 1(7):3-6, Jan. 1967.

A number of mathematical models can be applied to calculating the concentration of pollutants. In the dynamic model, the concentration of the effluents can be determined if the installation capacity and the parameters of dispersion are known. In the statistical model, the concentration of the pollutants derived from one or more sources is calculated. The most important mathematical model for pollution deals with the basic problem of diffusion in the lower atmospheric strata as a function of the special position of the source of pollution. The complete diffusion cycle of the effluents can be separated into three stages (according to Fuguay): 1) aerodynamic - dealing with the effects of turbulent, mechanical, and thermal motions on buildings and chimneys, including the geometry of the structure and the direction of the wind velocity; 2) the thrust effect, where velocity, density, and volume of emissions are involved (also wind velocity, vertical air density, atmospheric turbulence, and air shear); and 3) the dispersion of meteorological dilution, that is, the dispersion of meteorological diultion, that is, the dispersion of the contaminants by means of natural atmospheric turbulence. The author suggests that if diffusion is considered, then the best method of calculating coefficients is by the method of successive approximation. APTIC 5458.

123. Scorer, R. S.
THE BEHAVIOUR OF CHIMNEY PLUMES. Intern. J. Air Pollution, 1: 198-220, 1959.

The formulae available for computing the pollution due to an isolated chimney are too complicated to be of any practical use. The weather conditions in which they are correct are not usually the most important that can occur. Therefore, some simpler formulae are proposed: but these have to be used with discretion and with an understanding of the complexities of the actual weather.

The rise due to efflux momentum and buoyancy is calculated using simple formulae derived by dimensional analysis and simple experimental constants. The plume is assumed to be bent over when the upward velocity is about equal to the wind speed and the rise is assumed to be complete when the upward velocity is reduced to a certain fraction of the wind speed. When the rise is complete, the effluent is carried passively by the ambient turbulence. The formulae acknowledge three different regimes in which the efflux momentum, the buoyancy, and ambient turbulence successively dominate the mixing process.

When a plume contains liquid water an appreciable amount of heat may be lost when it evaporates on mixing with the environment. A diagram is given for computing the effect on the buoyancy. It may be enough to make the plume sink rapidly to the ground.

Finally, it is argued that architects should accept the chimney heights necessary for the proper dispersal of pollution as a requirement and design their buildings with the chimney as an integral part instead of as an undesirable appendage.

124. Scriven, R. A.
ON THE BREAKDOWN OF CHIMNLY PLUMES INTO DISCRETE PUFFS. Intern J. Air Water Pollution, 10:419-425, July 1966.

Estimates are made of the conditions under which cold source plumes with low efflux velocity break down into series of discrete puffs during the early stages after emission. It is found that the essential parameter is the ratio of initial plume diameter to the scale of atmospheric turbulence and that early breakdown occurs if this ratio is less than about 0.2. In many instances this can be interpreted as saying that the ratio of stack diameter to stack height is such that breakdown will occur in all but fairly stable meteorological conditions. The theoretical and laboratory situation regarding the study of hot sources is less clear and further work is necessary. The evidence that does exist indicates that the bent-over thermal jet is subject to inherent longitudinal breakdown. As suggested concurrently by Moore (1966) on the basis of field observations this means that plume rise calculations ought to be based upon three-dimensional entrainment models rather than the conventional two-dimensional one. APTIC #1517.

125. Scriven, R. A.
PROPERTIES OF THE MAXIMUM GROUND LEVEL CONCENTRATION FROM AN ELEVATED SOURCE. Central Electricity Research Labs., Leatherhead, England. (Presented at the Symposium on Chimney Plume Rise and Dispersion, Oct. 7, 1966.)

Simple one and two layer models of the atmosphere are used to derive properties of the downwind position and height of the maximum in mean ground level concentration which can affect either the handling or the interpretation of field data. It is shown that this maximum is quite flat, implying that whilst the peak value can be found accurately its position will be subject to large errors. The effect of stable layers above the source are also discussed and it is indicated how much of the scatter in field results can be attributed to this cause. APTIC #1934.

126. Simon, C. and B. W. Proudfit
SOME OBSERVATIONS OF PLUME RISE AND PLUME CONCENTRATION DISTRIBUTION OVER NEW YORK CITY. Preprint. (Presented at the 60th Annual Meeting, Air Pollution Control Assoc. Cleveland, Ohio, June 11-16, 1967.)

The various techniques employed in sampling discrete plumes from power plants in the New York City area by use of an instrumented helicopter are discussed and evaluated. An instrument package developed for this purpose containing an SO_2 analyzer with a time constant of 2.5 sec. and a fast response temperature sensor is described. It is shown that plume rise and plume geometry including the position of plume centerline in space can be determined with reasonable accuracy from the sampling of isolated plumes. More significantly, it is possible to observe the behavior of these plumes in the presence of the multiple inversion layers often found in the urban atmosphere. Some evidence is presented which indicates that plumes sometimes penetrate weak low-level inversions and also overshoot their equilibrium levels thus developing negative buoyancy and temperature deficits of more than 1 C on their decent. APTIC #6432.

127. Slawson, P. R.
OBSERVATION OF PLUME RISE FROM A LARGE INDUSTRIAL STACK. Waterloo Univ., Ontario, Canada. (Rept. No. NYO-3685-7) May, 1966.

Careful photographic observations were made on the rise of smoke plumes from Lakeview Generating Station, Ontario and the results were compared with several theoretical formulae. Data relating to the stack variables were collected in some detail. In a neutral atmosphere a linear rising portion of the plume was found to occur beyond a specific transition point. Within the limited accuracy of the photographic technique, the observations confirmed the theoretical result that the height of the plume axis above the source varies as the two-thirds power of the distance downwind. Increased dilution tends to oppose plume rise but the direct effect of instability in the atmosphere is to promote rise; under these opposing influences it was found that in a dynamically unstable atmosphere the plume is sometimes above or below a corresponding plume in neutral conditions. APTIC #5392.

128. Slawson, P. R. and G. T. Csanady
ON THE MEAN PATH OF BUOYANT, BENT-OVER CHIMNEY PLUMES. J. Fluid Mech., 28(2):311-322, 1967.

Plume-rise was observed by photographic means on smoke plumes from the Lakeview Generating Station (Ontario) and compared with some existing theoretical formulae. Supporting data in considerable detail on stack parameters were available. Source and environmental data for the eight experiments are summarized. Three experiments were carried out during neutral conditions. The observed plume paths in these three experiments are shown. A computer analysis of these three plume paths showed that the slope of each plume became constant (within the experimental scatter) beyond a certain non-dimensional distance, which was approximately the same in each of the three cases, although the slopes were individually different. There was thus a fairly definite transition point (or perhaps a short transition zone) at which the character of the plume changed. Between the chimney and the transition point, a non-dimensional plot of the three plumes coincided almost exactly, giving a 'universal' plume shape in the initial phase. In an unstable atmosphere the plume was sometimes above and sometimes below a corresponding plume in neutral conditions, under the opposing influences of increased dilution and the direct effect of instability in promoting plume rise. APTIC #7801.

129. Smith, M. E.
THE RELIABILITY AND APPLICABILITY OF DIFFUSION ESTIMATES IN AIR POLLUTION PROBLEMS. *Air Pollution Control Assoc. Proc., Semi-Ann. Tech. Conf.*, San Francisco, Calif., 1957. p. 106-117.

It is the purpose of this paper to examine the current status of the problem of the development of diffusion data and theory and to define the position in reference to the ultimate goal of standard engineering practice. An analysis of the mathematical and physical processes associated with atmospheric diffusion is not very encouraging in terms of the accuracy of practical diffusion predictions. Not only is the mathematical treatment far from rigorous, but inadequate field data leave many important gaps in the estimation of suitable values of the parameters. No standard accuracy figures can be given, but for various types of sources reasonable estimates of reliability are possible. Simple sources located in flat terrain can be described in terms of concentration to better than plus or minus 50% in lapse conditions. During nocturnal conditions, the accuracy is very much reduced owing to a lack of suitable experimental data. As the complexity of the plant and the terrain surrounding it increases, the accuracy of diffusion estimates deteriorates rapidly. Estimates of this type are ultimately dependent on field experiments for reliability, and the publication of such results by industry and for reliability, and the publication of such results by industry and research organizations is to be encouraged. Even the dissemination of relative values where company policy makes it impossible to publish original data will be of great value. APTIC #5799.

130. Smith, M. E.
THE STATUS OF METEOROLOGICAL KNOWLEDGE AS A FACTOR IN AIR POLLUTION CONTROL. *Proc. Natl. Conf. Air Pollution, Wash. D. C.* 1962. p. 260-266. Also Brookhaven Nat. Lab. Rept. No. 6538.

It seems certain that carefully planned, interdisciplinary attacks on the large-scale air pollution problems are the only means of elevating these efforts to a scientific, rewarding level. To accomplish this effectively, all disciplines, including meteorology, must participate actively from the earliest planning to the final evaluation of such programs; such a situation is rare enough to be called unique today. APTIC #4597.

131. Smith, M. E.
THE USE AND MISUSE OF THE ATMOSPHERE. Brookhaven Nat. Lab., Upton, N. Y. (*Brookhaven Lec. Ser.* #24) p. 18. Feb. 13, 1963.

Air pollution is discussed in terms of its relationship with various meteorological phenomena. The roles of wind, temperature and turbulence are elucidated. Also described are the settling of particles from a point source and the effects of topography. APTIC #6464.

132. Smith, M. E.
METEOROLOGICAL TOOLS FOR AIR POLLUTION CONTROL. *J. Air Pollution Control Assoc.* 14:(3) 80-82, 1964.

This paper deals exclusively with meteorological facilities, techniques and capabilities pertinent to air pollution control problems. Discussion of their utilization is deliberately avoided, since that subject is to be covered in a companion paper in the session. An attempt is made to define the various meteorological tools of importance in this field, and to indicate to the potential user something of their nature, quality, and status of development. Considerable detail is included regarding existing meteorological record, both public and private, as well as general specifications of instruments and data handling techniques. The most important tool, professional capability, is examined both from the point of view of current ability to solve air pollution problems and in terms of future needs as well. APTIC #2769.

133. Smith, M. E. and L. A. Cohen
AN ISOTOPIC RATIO TRACER TECHNIQUE. In: Proc. of the USAEC Meteorological Information Meeting held at Chalk River Nuclear Laboratories, Sept. 11-14, 1967. Mawson, C. A. (ed). p. 347-355.

Brookhaven National Laboratory has recently investigated the feasibility of utilizing naturally-occurring differences in the stable isotopes of sulfur as a means of identifying SO_2 and sulfates with the major sources from which they originate. This technique involves sampling of the SO_2 from the atmosphere by a chemically treated filter, a series of chemical conversions and finally determination of the isotopic ratios on a mass spectrometer. The details of this tracer system and its initial field results are summarized. APTIC #10058.

134. Snowball, A. F.
DEVELOPMENT OF AN AIR POLLUTION CONTROL PROGRAM AT COMINCO'S KIMBERLEY OPERATION. J. Air Pollution Control Assoc., 16: 59-62, 1966.

During the concentration of lead and zinc sulfides from Cominco's Sullivan Mine at Kimberley, British Columbia, there is also produced an iron sulfide concentrate as a byproduct. A portion of these iron concentrates is roasted and the resulting calcine is treated in electric furnaces to produce 300 tons of pig iron per day. The sulfuric acid which is employed in the manufacture of ammonium phosphate fertilizers. Problems in the control of air pollution resulting from the iron sintering, iron smelting, and fertilizer operations at Kimberley are discussed, including those arising as a result of almost continuous expansion of these facilities since their establishment 12 years ago. APTIC #4946.

135. Spurr, G.
THE PENETRATION OF ATMOSPHERIC INVERSIONS BY HOT PLUMES. J. Meteorol., 16:30-37, 1959.

Power-station chimneys emit hot gases which may be sufficiently buoyant to penetrate inversions associated with periods of smog. Two notable instances of smog in Great Britain have been examined, applying formulae derived by Sutton and Priestley. A method was suggested whereby an estimation may be made of the amount of heat required to ensure the penetration of an inversion by a plume.

136. Steinback, R. S.
STACKS FOR POLLUTION CONTROL. Chem. Eng., 59:202-203, Feb. 1952.

A discussion on stack heights needed for effective control of pollution by dispersion into the atmosphere is presented. A formula for the determination of the maximum ground concentration is derived from the general concentration equation of Bosanquet and Pearson.

137. Strom, G. H., M. Hackman, and E. J. Kaplin
ATMOSPHERIC DISPERSAL OF INDUSTRIAL STACK GASES DETERMINED BY CONCENTRATION MEASUREMENTS IN SCALE MODEL WIND TUNNEL EXPERIMENTS. J. Air Pollution Control Assoc., 7(3):198-203, Nov. 1957.

In an attempt to improve the visual and photographic methods a refinement was developed at the New York University Wind Tunnel to remove some of the human element in gauging smoke plume characteristics. The presence or absence of smoke - usually at ground level - was detected by the interruption of light in a beam projected across the airstream and directed at a phototube. Reduction in phototube output was an indication of the presence of the smoke plume at the level of the light beam. The possibility of developing the lighbeam technique into a point concentration type was studied. Results of experiments on a simple scale model with one stack are given. The results of SO_2 measurement are expressed as a ratio of concentration at sampling point to concentration in stack by vol. Comparison of concentration profiles of the plume from the simple stack with those having the building present show two general effects of building interference. With the building present, plume heights are 210 ft. with a north wind and 230 ft. with an east wind, both lower than the simple stack plume. In contrast with the vertical profile of the simple stacks, those with the building present showed a decided asymmetry. The concentrations in the regions below the peak are greater than those above. In application to air pollution problems of industrial plants the effects of plant configuration and stack parameters can be evaluated more effectively. Since tolerance of air pollutants is often expressed in terms of concentration values, direct measurement of concentrations in model experiments gives a more meaningful result. APTIC #5872.

138. Strom, G. H. and E. J. Kaplin
PLUME RISE CHARACTERISTICS OF A SCALE MODEL SMOKE PLUME. (In: Radiological Physics Div. Annual Report - July 1963 through June 1964.) p. 257-273.

The development of equipment and techniques for conducting scale-model wind-tunnel experiments on the atmospheric diffusion of smoke plumes is a principal objective of the experiments discussed. The experiments were conducted in the New York University Air Pollution Wind Tunnel. A 1/96 linear scale model of the Argonne Experimental Smoke Stack (17.5 in. inside diameter, 110 ft. high, prototype dimensions), produces the smoke plume. The plume is made visible for photographic purposes by introducing an oil-fog type of smoke. The multiple-exposure technique is used in photographing the plume to obtain the outline of the plume formed over a period of time. Sixteen exposures were made at 2-sec intervals on each negative. All of the test results presented are expressed in terms of numerical values at prototype scale. Between two test series various modifications were made in the wind-tunnel equipment to improve thermal control. An instrument towing chamber was developed to obtain more accurate calibration of the hot-wire anemometer used to measure the air speed. Techniques of data reduction and analysis were improved. It is believed that the second test gave a more accurate set of data than the first because of improvements in techniques, control, and calibration equipment. APTIC #6474.

139. Stumke, H.
INVESTIGATING THE TURBULENT PROPAGATION OF CHIMNEY GASES OVER UNEVEN TERRAIN. Staub (Eng. Transl.) 26(3):11-21, March 1966.

Earlier investigations into turbulent propagation of chimney gases under the influence of a form of ground are extended for further simple types of ground. Numerical calculations of the examples show that the method, in which the correction factor for the effective chimney height is derived from the air flow pattern, is useful as long as the smoke stream does not reach near a point at which a singular flow line degenerates into a flow plane. APTIC #2690.

140. Sutton, O. G.
THE DISPERSION OF HOT GASES IN THE ATMOSPHERE. J. Meteorol., 7: 307-312, 1950.

The problem of the dispersion of a stream of hot gas from a point is considered. It is shown that a plausible assumption concerning the mechanism of entrainment of air by the jet leads to simple expressions for the mean temperature and mean velocity of a jet of hot air rising in a calm atmosphere of uniform potential temperature.

141. SYMPOSIUM ON PLUME BEHAVIOR. Intern. J. Air Water Pollution, 10 (6/7):393-409, July 1966.

Two aspects of plume behavior were discussed: (1) Plume rise, and (2) The effects of buildings and topographical features on plumes. Specific topics discussed under those headings were: the rise of hot plumes in the atmosphere; the rise of hot plumes from chimneys; the penetration of an inversion layer by an industrial plume; experiments on the behavior of effluent emitted from stacks at or near the roof level of tall reactor buildings; and, indoor pollution in Rotterdam homes. APTIC #7052.

142. Telford, J. W.
THE VERTICAL PENETRATION OF HOT PLUMES. Jour. Rech. Atmospheriques 3 (1):1-8, Mar. 1967.

The author's theory of isolated thermal plumes is applied to the problem of a chimney plume rising in the turbulent air against a stable temperature gradient. Various modifications to the radius, updraft velocity, and related temperature excess are discussed in terms of the maximum rise of the plume. Adding external air accelerated to plume velocity offers the greatest theoretical benefit, but no attempt has been made to assess its engineering feasibility. Although the underlying theory of this analysis has not been confirmed by direct experimentation, it points the way toward a more realistic understanding of the problem and offers an approach to decide whether a proposed modification is likely to be effective. APTIC #7194.

143. Terraglio, F. P. and R. M. Manganelli
THE ABSORPTION OF ATMOSPHERIC SULFUR DIOXIDE BY WATER SOLUTIONS.
J. Air Pollution Control Assoc., 17(6):403-406, June 1967.

Results of a laboratory study indicate that the rate of solution of atmospheric SO_2 in distilled water, over the range of atmospheric concentrations of 0.81-8.73 mg SO_2/cu m, is a function of the concentration of SO_2 in the atmosphere, with saturation being reached more rapidly at the higher concentrations. This would indicate that rain water, with constantly renewed surfaces, can be very effective in the removal of atmospheric SO_2. The pH of the exposed water samples reached values of 4.0 or less, comparable to values observed in fog and cloud near large industrial areas. Overall solubility of SO_2 in distilled water did not follow the law of partial pressure. At the atmospheric concentrations used it was found that over 98.5% of the sulfite in solution was in the form of the HSO_3^- ion with the remainder present as unionized H_2SO_3 acid. Computations using the concentration of unionized H_2SO_3 acid in the solution showed that the solubility of this portion of dissolved sulfite did follow the law of partial pressure. APTIC #6080.

144. Teubner, J., K. Horn, A. Knauer and K. Hammje
AIR-HYGIENIC MEASUREMENTS OF THE RELATIONSHIPS BETWEEN SO_2
IMMISSION, NUMBER OF NUCLEI, NUMBER OF GERMS AND METEOROLOGICAL
FACTORS. (Lufthygienische Untersuchungen uber Beziehungen
zwischen SO_2-Immission, Kernzahl, Keimzahl und meteorologischen
Faktoren.) *Z. Ges. Hyg. Grenzg.* (Berlin), 11(7):497-500,
July 1965.

The relations between SO_2-immission, number of nuclei, number of germs, as well as the meteorological factors of air temperature, wind velocity and rainfall were observed at two measuring points -- a dwelling area and an industrial area -- of a big city for one year's time. The number of nuclei changed in the same direction as the SO_2-immission. This was due to their same sources of origin. The number of nuclei changed counter-directionally towards the temperature. This was due to a secondary influence exerted by the heating processes dominating in winter, as well as by the improved exchange conditions of atmospheric air existing in summer. The SO_2-concentrations were directly dependent on the rainfall conditions; there exist secondary relations with the air temperature. Relations between the number of germs and the SO_2-immission however, existed only at one measuring point and even there only under certain bacteriological experimental conditions. All further comparisons, particularly those concerning the number of germs and the number of nuclei, air temperature, wind velocity and rainfall revealed that the measuring values obtained were completely independent of one another. The number of germs is of no practical importance as an air-hygienic indicator for characterizing the pollution of the atmospheric air. APTIC #6204.

145. Turner, D. B.
COMMENTARY ON "FULL-SCALE STUDY OF DISPERSION OF STACK GASES."
Preprint. 1964.

The Xu/Q's (from maximum concentrations) and the Xu/Q's (from dispersion parameters) are compared. Factors which might contribute to differences are cited: (1) distribution of plume concentrations may not be quite Gaussian in either the horizontal or vertical; (2) true wind speed may differ from wind speed at the plume level used to calculate the value from maximum concentrations; (3) sampling errors; (4) transformation of SO_2 into some other atmospheric constituent. The validity of the techniques is attested to by good correlation of results. APTIC #1841.

146. Turner, D. B.
WORKBOOK OF ATMOSPHERIC DISPERSION ESTIMATES. Public Health
Service, Cincinnati, Ohio, National Center for Air Pollution
Control, PHS-Pub-999-AP-26, 1967.

Methods of practical application of the binormal continuous plume dispersion model to estimate concentrations of air pollutants are presented. Emphasis is on the estimation of concentration from continuous sources for sampling times of 10 minutes. Some of the topics discussed are determination of effective height of emission, extension of concentration estimates to longer sampling intervals, inversion break-up fumigation concentrations, and concentrations from area, line, and multiple sources. Twenty-six example problems and their solutions are given. Some graphical aids to computation are included. APTIC #9712.

147. Turner, J. S.
INTERMITTENT RELEASE OF SMOKE FROM CHIMNEYS. J. Mech. Eng. Sci.,
2(2):97-100, 1960.

Dimensional arguments and the results of recent laboratory experiments are used to show that a considerable increase in the height attained in a calm stable atmosphere could be expected if the effluent were forced out of chimneys at high velocity in discrete puffs, rather than continuously. Numerical values are given for the final height, the size of the chimney and the optimum storage and release times under various conditions. An important application is likely to be noxious gases which could be removed to a safe height with very little mixing into the atmosphere at lower levels. APTIC #4554.

148. Ukeguchi, N., H. Sakata, H. Okamoto and Y. Ide
STUDY ON STACK GAS DIFFUSION. Mitsubishi Tech. Bull., No. 52:
1-13, Aug. 1967.

The estimation of ground level concentration by theoretical and empirical diffusion formulae is reviewed. Wind tunnel experiments done in the Aero-Hydraulic Laboratory, Nagasaki Technical Institute are summarized. APTIC #8833.

149. Vadot, L.
STUDY OF DIFFUSION BY MEANS OF AN HYDRAULIC ANALOGY. (Etude de la Diffusion au Moyen d'une Analogie Hydraulique.) Proc. (Part I) Intern. Clean Air Cong., London, 1966. p. 216-218.

In order to study atmospheric diffusion phenomena with density effects use was made of an inverted hydraulic analogy. Thus, the cold and warm air masses were represented by fresh and salt water respectively. The weight relationships being reversed, the smoke plumes on the model travelled downwards instead of upwards. Visualization of the phenomena is facilitated by this method, as is also the measurement of pollution concentrations, the latter being carried on continuously by conductivity meters. The proposed method of investigation was found to be suitable for studying problems such as: (a) ascent of smoke plumes due to thermals; (b) behaviour of a plume affected by a thermal under temperature inversion conditions; (c) combination of density and relief effects; (d) investigation of pollution in wake eddies due to buildings. APTIC #2058.

150. Wippermann, F. and W. Klug
MINIMUM SMOKE STACK HEIGHTS. THEIR DETERMINATION FROM THE PRINCIPLES OF TURBULENT DIFFUSION IN THE ATMOSPHERE. (Schornsteinmindesthöhen Ihre Bestimmung aus Gesetzmässigkeiten der turbulenten Diffusion in der Atmosphäre.) (Verein Deutscher Ingenieure, Kommission Reinhaltung der Luft.) Soc. of Ger. Engineers, Commission for Air Purification, Darmstadt. July 1960. Ger. (Tr.).

The physical laws of atmospheric turbulent diffusion are utilized in determining the minimum smoke stack height required to prevent excessive gas concentrations near the ground. This report allows objective calculation of the minimum stack heights, i.e., it replaces various basically different procedures previously employed. This manual prescribes the same stack heights for emission sources of the size under similar conditions and in addition, the stack heights it prescribes for emission sources of various sizes stand in an objective, physically established relationship to each other. APTIC #5271.

151. Wipperman, F.
DIAGRAM FOR ESTIMATING THE APPLICABILITY OF CHIMNEY HEIGHTS TO AIR PURIFICATION CONDITIONS. (Diagramme zur Beurteilung der Eignung von Schornsteinhohen für die Luftreinhaltung.) Technische Hochschule Darmstadt Institut fur Meteorologie. Sept. 1963. Ger. (Tr.)

If the frequency distribution of the wind velocity is considered the most important meteorological parameter in the diffusion theory, diagrams can be drawn up which allow statements on the maximum of the surface concentration of harmful gases which are emitted, and the frequency of its occurrence and position. Also, statements on the frequency of concentrations in excess of the fixed, greatest permissible value and similar matters are possible. APTIC #4614.

MISCELLANEOUS

152. ASME Standard 1966. RECOMMENDED GUIDE FOR THE CONTROL OF DUST EMISSION -- COMBUSTION FOR INDIRECT HEAT EXCHANGERS. ASME Standard No. APS-1, The American Society of Mechanical Engineers. New York, N. Y.

This standard on air pollution is an outgrowth of an Information Bulletin, "Example Sections For a Smoke Regulation Ordinance", prepared by the Model Smoke Law Committee, Fuels Division, The American Society of Mechanical Engineers, May, 1949. Because of an increase in discharge of waste materials to air brought on by an expanding population, the ASME Committee on Air Pollution Controls started a review of the Ordinance in 1959.

153. Barry, P. J.
FREQUENCY OF OCCURRENCES OF MAXIMUM POLLUTION LEVELS FROM SINGLE STACKS. Presented at the National Meteorology Congress, Royal Meteorological Society, Sherbrooke, Quebec, June 8-10, 1966.

A radioactive noble gas, Argon 41, was discharged continuously from the Chalk River Nuclear Laboratories (CRNL) stack at an almost constant rate. The concentration of the gas at ground level has been measured continuously at four sampling stations at various distances around the stack. The magnitude of extreme pollution levels occurring in the vicinity and also the frequency with which extreme levels of different magnitudes occur have been estimated from the results. The occurrence of extreme pollution levels is related to such meteorological variables as atmospheric stability and wind turbulence. APTIC #8853.

154. Bender, Rene J.
AN UNUSUAL APPROACH TO AIR POLLUTION CONTROL. Power, p. 83, Dec. 1966.

At Vouvry in Switzerland, near the Rhone river and close to the French border, the inhabited portion of the valley is at 1200 feet above sea level, while the inversion level is at 2250 feet. Before being allowed to construct a thermal power plant, Energie de l'Ouest Suisse S A had to promise that the flue gases would be released above that lid of atmospheric inversion. A power station was built, supplied with both fuel oil and make-up cooling water through a 1200-ft rise. The station consists of two boilers, each supplying 1 million lb. per hr. of steam at 2700 psi and 1005/1005° F, and two 130 mw turbine generators. One of the three feedwater pumps is driven by a steam turbine and consumes 4375 kw. The turbojets consist of a high-pressure and an intermediate-pressure turbine, a triple-flow low-pressure turbine, and a hydrogen-cooled generator. Precautions taken to avoid air pollution, in addition to the high elevation and the tall stack, also minimize boiler fouling and eliminate low-temperature corrosion. Excess air, maintained at a low level of 3.5 to 5%, is allowed to reach 10 to 12% only at low loads, about 30% of boiler capacity. Magnesium oxide is air-blown into the furnace between the 3rd and 4th burner levels (a stack of four reflux burners are installed in each corner of the combustion chamber). To keep the flue gases above the dew point, their temperature is increased from 256-266 F at full load to 284 F at low load. No flue gas cleaning device was planned. APTIC #7996.

155. Bresser, H. and W. Hansch
A METHOD FOR CALCULATING SO_2 IMMISSIONS IN THE SURROUNDINGS OF LARGE POWER STATIONS. Staub (Eng. Transl.), 25(6):20-24, June 1965.

A method is described which makes possible a statistical calculation of the SO_2 immissions to be expected in the surroundings of a large power station. The calculation method is based on the determination of propagation parameter according to Sutton, combined with a correction of the propagation formula with regard to the change in the average wind direction. The required exponents can be evaluated if the daily weather reports are interpreted as a function of wind velocity profiles. The results are compared with calculations based on the Pasquill method. APTIC #2368.

156. Breuer, W. and K. Winkler
SULFUR DIOXIDE IMMISSION DURING CALM WEATHER. STAUB (English translation), 25(3):18-24, Mar. 1965.

Sulfur dioxide emissions measured in the Cologne-Leverkusen area show that when the weather situation is still, the emissions from lew-level sources are important in the accumulation of sulfur dioxide near to the ground, whilst emissions from high chimneys are of less significance. By means of parallel sulfur dioxide and carbon dioxide measurements it has been possible to identify the emitting groups responsible for these accumulations of emissions. APTIC #2649.

157. Brief, R. S.
AIR POLLUTION FROM STACKS. Air Conditioning, Heating, Ventilating, 62(7):61-66, July 1965.

Techniques are presented for estimating ground level concentrations of air contaminants released from stacks, vents, and other elevated sources. In each technique, besides knowing the properties of the effluent it is necessary to know or estimate the dispersive capability of the atmosphere. Using charts or simplified formulas, developed from the work of Pasquill, dispersion estimates can be readily obtained. A simplified technique for estimating effective stack height is also presented. This article has brought together formulas found useful by the author from different sources. They have been made self-consistent so that initial conversion of the data to the dimensions chosen will produce the desired results. More accurate results may be obtained by collection of extensive meteorological data, wind tunnel experiments and the like. However, for rapid use in the field where accuracy may be compromised for expediency, these suggested formulas are practical and useful. APTIC #4780.

158. Brink, J. A. and B. B. Crocker
PRACTICAL APPLICATIONS OF STACKS TO MINIMIZE POLLUTION PROBLEMS. Jour. of the Air Pollution Control Assoc., 14(11):449-454, Nov. 1964.

"Rules of thumb" for stack design have been developed for use on problems where extensive studies cannot be justified or where quantitative design data are unavailable. The application of these rules to a practical stack design problem is discussed. The IBM 704 computer has been used for rapid yet rigorous stack design studies. The computer procedures for design are discussed and its application to a practical problem is described in detail. APTIC #5063.

159. Carter, J. S.
CHIMNEY DISPERSAL OF INDUSTRIAL WASTE GASES IN THE 19th AND 20th CENTURIES. Public Health Inspector (London), 73:405-410, July 1965.

The history of stacks for dispersal of industrial waste gases in Great Britain is reviewed. APTIC #1416.

160. Clarke, A. J., G. Spurr and S. Catchpole
TOWARDS A CLEAN AIR POLICY. Proc. (Part I) Intern. Clean Air Cong., London, pp. 203-205. 1966.

The paper considers some fundamental concepts of a rational clean air policy, and stresses that the control of ground level concentrations should be the primary concern. The basic relationship determining ground level concentrations includes both the rate and effective height of emission, both of which must be taken into account in an effective control policy. Furthermore, the latter should permit flexibility in selecting the method of control most suited to the circumstances, including feasibility and cost. The principles applied by the Central Electricity Generating Board (C.E.G.B.) to the control of smoke, dust and sulphur dioxide from power stations are described. Recent advances in the design of plants include the development of the single tall multiflue chimney. Air pollution surveys and measurements, both in the vicinity of power stations and nationally, have demonstrated the effectiveness of the clean air policies practiced by the C.E.G.B. APTIC #2052.

161. Craxford, S. R.
AIR POLLUTION FROM POWER STATIONS. Smokeless Air (London) (Excerpts from a Paper read to the Pro Aqua Congress, Basle, March 1965). 36:123-128.

A large modern power station, for example, a station of 2,000 megawatts capacity, emits annually about the same amount of atmospheric pollutants-grit and dust, and sulphur dioxide - as an industrial city of a million inhabitants. The main problem of air pollution from power stations is to keep short-period maximum concentrations within tolerable limits. Grit and dust; and the natural dispersion of sulphur from high chimneys are considered. APTIC #1350.

162. Croome, D. V.
CHIMNEY DESIGN. J. Inst. Heating, Ventilating Engrs. (London) 34:165-174, Sept. 1966.

Reasons for rationalizing a chimney design are discussed. Using the SO_2 rate of emission and type of district, the so-called uncorrected chimney height is found using nomographs. A correction to this height is necessary if it is less than 2-1/2 times the building height or the height of nearby buildings. Again using nomographs the final chimney height is established by considering the uncorrected height in relation to the building dimensions. The problem is corrosion and methods for its prevention are discussed. Finally, chimney design procedure is outlined together with present research work and future aspects of design development. APTIC #1765.

163. Dickie, W. J.
SOME INDUSTRIAL PROBLEMS ARISING FROM THE CLEAN AIR ACT 1956. Proc. (Part I) Intern. Clean Air Cong., London, 1966. p. 89-91.

The Clean Air Act contains no reference to a standard rate of emission of grit and dust from furnaces and pressure has arisen for their formulation. Standards should be based on simple and inexpensive methods of measurement sufficiently accurate for the purpose, and on readily available facts. The levels should be realistic and when applied for the first time, should be consistent with the rates of emission that can be achieved by good practice. Wide-scale investigation is necessary before realistic standards can be determined for certain types of furnaces. Conflicting views are often expressed by Public Health and Town Planning Authorities in determining acceptable heights for chimneys. Failure to reconcile opposing views can in some case restrict the choice of fuel. APTIC #2016.

164. Elshout, A. J.
THE MEASUREMENTS OF DUST AND GASEOUS AIR POLLUTIONS IN THE VICINITY OF AN ISOLATED POWER STATION. Staub (Eng. Transl.) 25(11):37-41, Nov. 1965.

The results of dust precipitation measurements and sulphur dioxide measurements carried out for many years in the vicinity of a power station are reported. Within a radius of 3 km the precipitated fly ash was only 3% of the total amount emitted from the power station. The measured values were in good agreement with calculated values. In contrast to this the measured SO_2 concentrations were 50% higher or lower than the theoretical values. A higher value was obtained for the Cz value in Sutton's formula. The different methods for calculating the minimum stack height must be checked and adapted by adjusting the coefficients. APTIC #2979.

165. Elshout, A. J. and H. Van Duuren
SULFUR DIOXIDE AIR POLLUTION NEAR STEAM POWER PLANTS. (Luchtverontreiniging door zwaveldioxyde rondom elektriciteitsproduktiebedrijven.). Text in Dutch. Electro-Techniek (The Hague), 45 (5):103-112, Mar. 1967.

Short-term, downwind SO_2 levels were measured downwind of two power stations. In both cases, the maximum 30-min. average ground-level concentration was lower than the maximum allowable concentration; the long-term average concentrations from the stations were small and less than the background concentration. Mean values of maximum concentration agreed with, or ranged up to twice those values calculated by using the Sutton diffusion equation with the Bresser-Hansch modification. Calculations based on the West German Technical Instruction and VDI-Directive 2289 resulted in maximum SO_2 values which were 6 times higher than mean values actually found. Mean distances from the chimneys of the points of maximum concentration, deduced from ground-level concentration profiles along the plume-axis, were considerably smaller than the theoretically calculated ones. The values of the diffusion coefficients used are thus too small to give a reasonable description of plume dispersion. It is concluded that power stations with adapted chimney-heights, such as those built in the Netherlands during the past 10 years, generally do not cause SO_2 pollution above the maximum allowable concentration. APTIC #8799.

166. Frankenberg, T. T.
AIR POLLUTION FROM POWER PLANTS AND ITS CONTROL. Proc. Natl. Conf. Air Pollution, Washington, D. C., 1962. p. 95-100. 1963.

This is a report from the utility industry on the status of thermal power plants and of its present problems, which are the sulfur oxide control from coal and combustion gases. The method of adjusting this problem has been to exercise a great deal more care and foresight in the selection of stack heights, giving due consideration to the expected local meteorological conditions, to the end that sulfur oxides will be fully and effectively diffused in the atmosphere, and thus become a problem at ground level. Along with the tendency to install larger power units, the industry also has witnessed a rather sharp increase in the total amount of power installed on one site. While in 1952 the largest thermal plant did not quite reach 1,000 megawatts in size, there are today (1962) 15 plants which exceed the mark, one by as much as 40 percent. There is a general upward trend in stack height, although differences in plant sites, fuel burned, population density, proximity to airports, and possibly other variables, create wide individual differences among the plants. APTIC #4586.

167. Gartrell, F. E. and J. C. Barber
POLLUTION CONTROL INTERRELATIONSHIPS. Chem. Eng. Progr., 62 (10):44-47, 1966.

Authors conclude that air pollution control and water pollution control in industrial applications are closely related. Discussed are the TVA experience with coal-fired power plants and phosphate fertilizer plants which indicates that application of one type of pollution control ultimately must include consideration of the other. General aspects of the control equipment (to control fly ash emissions) utilized in the TVA coal-fired power stations are discussed. APTIC #2192.

168. Gasiorowski, K.
THE USE OF PROPAGATION FORMULAS TO CALCULATE MINIMUM CHIMNEY HEIGHTS WITH RESPECT TO THEIR ENVIRONMENT. Staub (Engl. Transl.) 27(4):1-5, April 1967.

A method of taking into account high single objects in the evaluation of minimum chimney heights is developed with the help of extended calculation. The method can also be used for measuring sections to be added to a chimney in the case of buildings or trees reaching the chimney height. On the basis of probability considerations, a simplification is proposed and discussed. APTIC #7722.

169. Gifford, F. A. Jr.
THE ELEVATION OF THE MEAN AND THE MODE OF THE GAUSSIAN CONCENTRATION DISTRIBUTION. Preprint. July 12, 1967.

The equations governing the height of the mean and the mode of the concentration distribution are derived. The elevation of the mean, or centroid of the concentration distribution is given by an equation and curves which are depicted. The elevation of the points of maximum concentration are also given by an equation and by curves. The behavior exhibited by these curves agrees at least qualitatively with what would be expected. Near the stack both the mean and the mode are located at stack height. Farther downwind, near the point at which the vertical spreading, σ_z, grows to near the stack height, the pattern changes. The height of the mean then increases, for both reflection and absorption as σ_z increases whereas, for reflection, the mode decreases abruptly to zero. APTIC #8852.

170. Grafe, K. and J. Hagen
MINIMUM STACK HEIGHTS AND AREA AROUND STACK WITHIN WHICH BUILDINGS MUST BE CONSIDERED. Staub (Eng. Transl.) (Dusseldorf) 26(9):41-43, Sept. 1966.

In order to calculate the distance from the stack covering the area where buildings have to be considered, a formula is derived from the equation for the distribution of the SO_2-concentration in the surroundings of a source. Thus a suggestion is made as a basis for discussion with regard to an addition to the TAL - Techn. Anleitung Reinhaltung der Luft - (a paper containing among other things rules for minimum stack heights). An example illustrates the possibilities of practical appliance. APTIC #3775.

171. Grafe, K. and J. Hagen
DETERMINATION OF MINIMUM STACK HEIGHT IN CONSIDERATION OF SURROUNDING BUILDINGS. Staub 26(9):391-392, 1966.

In order to calculate the area within which the surrounding buildings have to be taken into consideration in the determination of minimum stack height, a formula is derived from the equation for distribution of noxious gases around such a stack. The formula is intended as basis of discussion for complementing the "Guide for Elimination of Air Pollution"("TAL"). An example explains the possibility of practical application of the formula. APTIC #2923.

172. Halitsky, J.
ESTIMATION OF STACK HEIGHT REQUIRED TO LIMIT CONTAMINATION OF BUILDING AIR INTAKES. Am. Ind. Hyg. Assoc. J., 26(2):106-116, 1965.

When multiple sources release contaminants a short distance above the roof of a building, the gases are usually trapped in the eddy zone or cavity adjacent to the roof and side walls, and undesirably high concentrations may be produced at air intakes in the side walls. Since the side walls generally are regions of minimum concentration for exhausts located on the roof, the only recourse to effect a further reduction in concentration is to deposit some of the effluent outside of the cavity. This paper presents a method for calculating the stack height necessary to produce an arbitrary concentration at the side-wall intakes, by evaluating the partial entrapment of the plume in the cavity. APTIC #7066.

173. Hewson, E. W.
STACK HEIGHTS REQUIRED TO MINIMIZED GROUND CONCENTRATIONS. Trans. ASME, 1163-1172, Oct. 1955.

Aerodynamic and meteorological concepts are combined in a procedure for estimating round concentrations of effluents from stacks with various possible heights and exit gas velocities. The operation of each of the several influences at work is first described. A detailed example is then given of how the most important phases were integrated into a consistent procedure for predicting ground concentrations in answer to a specific design problem. Further improvements and refinements of the method are desirable and are being incorporated in a later study.

174. Hodkinson, J. R.
MONITORING STACK PARTICULATES BY OPTICAL TRANSMISSOMETER: A FURTHER NOTE AND 2 APPENDICES. Preprint. (Presented at the Stack Sampling and Monitoring Meeting, Coordinating Committee on Air Pollution, Engineering Foundation, Sterling Forest, Tuxedo, N. Y., Nov. 25-26, 1963.)

Most smoke-stack transmissometers can be conveniently modified by placing a lens, probably identical with that producing the collimated beam from the source, in front of the photocell, with a small aperture at its focus, beyond which the light passing through the hole diffuses out to cover the photocell sensitive area. Provision should also be made for inserting colbr filters before the aperture. A list of 17 manufacturers of smoke-stack transmissometers in the U. S. and 3 in West Germany as well as a method for the prediction of smoke-plume transmittance are appended. APTIC #4761.

175. Hughson, R. V.
CONTROLLING AIR POLLUTION. Chem. Eng., 73(18):71-90, Aug. 29, 1966.

A technical assessment of the air pollution abatement problem is presented. Future standards of air pollution control, costs, governmental control, and equipment for air pollution control are presented. Mechanical collectors (cyclones), cloth collectors, electrostatic precipitators, cyclonic scrubbers, venturi scrubbers, and wet scrubbers are dealt with in detail. Six design parameters relating to stacks for efficient air pollution control are also presented. APTIC #3157.

176. INDUSTRY AND ATMOSPHERIC POLLUTION IN GREAT BRITAIN. (Industrie et pollution atmospherique en Grande Bretagne.) Centre Interprofessionnel Technique d'Etudes de la Pollution Atmospherique, Paris, France. Fr. (Rept. No. CI 310) (C.I.T.E.P.A. Doc. No. 24.) 1967.

A summary of the basis of governmental action in Great Britain in the struggle against industrial emissions is outlined. The regulations imposed by the "Alkali Act" are in most cases based on "the most practical mean." Standards are given for chimney heights. Statutory limits are given for various materials emitted such as hydrochloric acid, sulfuric acid, nitric acid, hydrogen sulfide, chlorine, arsenic, antimony, cadmium, and lead. The construction of tall building tends to reduce the benefits obtained by tall chimneys. A better knowledge of the effects of pollutants should be obtained so as not to burden industry with unnecessary expense in their control. It is urged that international standards for emission be adopted. APTIC #6778.

177. INTERIM METHOD FOR COMPUTING THE ATMOSPHERIC SCATTERING OF WASTES (SOLS AND SULFIDE GASES) FROM THE STACKS OF ELECTRIC POWER STATIONS. Trudy Glavonoy Geofizicheskoy Observatorie (Transactions of the Main Geophysical Observatory) (Transl. as JPRS 34, 719) (172) 205-212, 1965.

On the basis of special theoretical and experimental investigations the computation method was evolved for determing the scattering from electric power station stacks, the height of the stacks, and the norms for emissions. APTIC #3000.

178. Jorg, O. and R. S. Scorer
AN EXPERIMENTAL STUDY OF COLD INFLOW INTO CHIMNEYS. Atmospheric Environ., 1(6):645-654, Nov. 1967.

The inflow of exterior fluid into a chimney from which buoyant fluid emerges was investigated in a water tank with some supplementary investigations in air. The original problem posed was how wide a cooling tower could be without cold air flowing in at the top, but since it became evident that the nature of the boundary layer in the outflowing fluid was more important than the dimension of the outlet the most important application seems to be to the prevention of cold inflow into chimneys of oil fired furnaces. Once cold inflow begins it may produce a cold patch on the chimney wall which has two effects. The first is to prolong the inflow down that part of the wall which causes deeper penetration and the second is to cause the condensation of vapours on to the cold wall. A formula representing the depth of penetration of the exterior fluid is given. The formula is applicable if the characteristic length (boundary layer thickness) is small compared with the chimney diameter, and this may explain some of the trends which are different for the smallest and largest tubes. In practice a cross-wind would generally be present. Cursory observation was made of the effect of this in the air experiments, and it was observed that the inflow tended to occur preferentially near the sides of the orifice rather than at the upwind and downwind edges, but there are effects such as chimney wall thickness and shapes such as are common among cooling towers which have not been investigated. If cold inflow penetrated below the neck of a cooling tower it would almost certainly reach the bottom because in the lower part either the velocity decrease downward or there are dead air regions through which the cold air could sink. APTIC #8854.

179. Juda, J. and K. Budzinski
ATMOSPHERIC POLLUTION. (Zanieczyszczenia Atmosfery.) Text in Polish. Warsaw, Wydawnictwa Naukowo-Techniczne. Engl. Transl. by JPRS:18:455, Mar. 1963.

Information about the sources, dispersion and investigation of atmospheric pollutants is reported. Results of studies from foreign sources are given, and an attempt is made to analyze these data in the light of conditions prevailing in Poland. The work is intended for engineers who plan industrial plants and supervise the operation of machinery and industrial installations, as well as for the safety and work hygiene service employees. Subjects discussed are: (I) Systematic Classification of Atmospheric Pollutants; (II) Sources of Atmospheric Pollutants; (III) Damage Caused by Atmospheric Pollution; (IV) Aerosol Mechanics; (V) The influence of Meteorological Conditions on the Dispersion of Pollutants; (VI) Dispersion of Pollutants in the Atmosphere; (VII) Method of Measuring Atmospheric Pollution; (VIII) Determination of Pollutant Emission; (IX) Estimation of Dustfall; (X) Determination of Particulate Matter Concentration; and (XI) Determination of Gaseous Air Pollutants. APTIC #7264.

180. Langmann, R.
CLEAN AIR MAINTENANCE - A TASK FOR THE OFFICE OF PUBLIC HEALTH. (Die Reinhaltung der Luft als Aufgabe des Gesundheitsamtes.) Oeffentl. (Stuttgart) 29(3):126-134, Mar. 1967. Ger.

Government regulations request that the office of public health pays attention to the maintenance of clean air. More specifically, it must screen projected industrial enterprises as to the degree of their expected air polluting emissions and the eventual impact on the health of the employees and the neighboring inhabitants. In cases where the office of public health through its investigations finds evidence of health hazards, it must recommend various ways of avoiding or eliminating the pollution of air. A large number of pollutants are discussed, such as dust, toxic gases, and obnoxious vapors and odors. Their sources and methods for their elimination are discussed in detail and represented by examples. Particular emphasis is placed on proper city planning, zoning, and a more stringent application of regulations concerning the construction of new plants, especially their chimneys. Further investigations into possibilities of remote heating and of substituting gas and electricity for coal are recommended. Finally, the importance of educating the public on the consequences of air pollution is stressed. APTIC #7235.

181. Lord, G. R., W. D. Baines and H. J. Leutheusser
ON THE MINIMUM HEIGHT OF ROOF-MOUNTED CHIMNEYS. RESULTS OF AN EXPLORATORY WIND TUNNEL STUDY. Toronto Univ., Toronto, Canada, Dept. of Mechanical Engineering (Tech. Pub. No. 6409). Oct. 1964.

Wind tunnel tests of smoke emission from roof-mounted chimneys on both block-type and pyramidal structures are described. The tests were performed in a constant velocity wind field and mostly under the condition of wind velocity equal to gas emission speed. Four conditions of minimum stack height, each corresponding to a different degree of plume distortion, are defined and pertinent results for various building configurations, stack locations and wind directions are displayed and discussed. APTIC #1869.

182. Ludwig, J. H., and R. A. McCormick.
THE METEOROLOGY PROGRAM OF THE NATIONAL CENTER FOR AIR POLLUTION CONTROL. National Center for Air Pollution Control, U. S. Dept. of Health, Education and Welfare, Washington, D. C.

Meteorology has been an integral part of the Federal air pollution program since its inception in 1955 by the passage of P. L. 159, an Act that provided for Federal research and technical assistance to States and local agencies in their efforts to control air pollution. Two types of meteorological activities have evolved over the years: (I) Research, which has focused on defining and describing meteorological factors of prime importance to air pollution control activities; (II) Application of meteorological principles to the conduct of air pollution control programs. These activities are discussed. Training objectives and the outlook after the Air Quality Act of 1967 are also discussed.

183. Martin, A. E.
EFFECTS OF POWER STATION EMISSIONS ON HEALTH. World Health Organization (WHO/AP/66.27). p. 43. 1966.

Prevailing levels of atmospheric pollution in St. Helens, Warrington and Widnes are high and the available evidence indicates that the incidence and mortality from bronchitis is also high. Atmospheric pollution is known to be an important contributing factor influencing both the number of cases and of deaths from this disease. Any proposal which might contribute towards an increased level of air pollution in the district must therefore be examined with great care. From the height at which the fumes from the proposed power station would be discharged and from the known behaviour of chimney emissions under varying weather conditions the evidence indicates that the power station would make but a tiny contribution to the prevailing ground level concentration of SO_2. Moreover the sulfur dioxide pollution from the power station would be of a transient nature and would only affect the surrounding area at times when the natural ventilation is good and ground pollution from local sources is low. At times, when owing to climatic conditions pollution from local sources is high, fumes from the power station would not descend to ground level within this area. For the reasons given in this report and subject to the acceptance in the main report of the findings on the evidence on chimney emissions, it is the author's opinion that the pollution from the proposed power station would not add any appreciable hazard to the health of the surrounding population. APTIC #0981.

184. Martin, A. E.
REPORT ON CHIMNEY EMISSIONS (RATCLIFFE-ON-SOAR POWER STATION).
Central Electricity Generating Board, England. p. 22, June 1966.

Document is the official report on air pollution by the Medical Assessor, following the Minister of Power's Public inquiry into the proposal by the Central Electricity Generating Board to build a 2,000 MW coal-fired power station at Ratcliffe-on-Soar, near Nottingham. After consideration of the existing knowledge of the medical effects of atmospheric pollutants, and of the concentrations of pollutants which would reach ground level from the proposed power station at Ratcliffe-on-Soar and be superimposed on the existing levels of atmospheric pollution in the area, the opinion that the power station emissions would not add any appreciable hazard to the health of the surrounding population is presented. APTIC #2417.

185. Martin, A. and F. R. Barber
INVESTIGATION OF SO_2 POLLUTION AROUND A MODERN POWER STATION.
J. Inst. Fuel (London) 39(306):294-307, July 1966.

Sixteen sulphur dioxide recorders have been sited around a modern 1000 MW power station situated in a rural area. The recorder layout was in the form of a ring, the radius of which was the distance of calculated maximum ground-level pollution. The results from their operation during the period October, 1963, to September, 1964, are reported. On a long-term basis the overall average effect of the power station on the concentration of sulphur dioxide as measured at these sites was small (0.1 to 0.2 p.p.h.m.) compared with that already to be found in the area (3 to 5 p.p.h.m.). Most of the pollution appeared to come from distant cities and industrial areas. The most persistent effect from the power station, amounting on average to only 0.6 p.p.h.m., was to the north-east of the station and is thought to be due to the combined effects of wind frequency and strength in that direction. Short-term (3-min) power station contributions were often detectable, but under the dispersing effect of the wind, were not usually persistent at any one site. There was no significant pollution from the power station in stable atmospheric conditions, with or without fogs. The importance of dosage, as well as peak and mean concentrations, is discussed. It is shown that the power station pollution and background pollution are rarely additive, and that only the background has given rise to objectionable dosages. Modifications to accepted methods of calculation are proposed, to account for absolute short-term maxima recorded. APTIC #1510.

186. McKarns, J. S., R. G. Confer and R. S. Brief
ESTABLISHED LENGTH LIMITS FOR DRAIN TYPE STACKS (TO PREVENT EFFLUENT BLOWOUT AT THE ANNULAR GAP BETWEEN UPPER AND LOWER SECTIONS). Heating, Piping, Air Conditioning, 37(7):107-109, July 1965.

Length limitation of drain type stack was studied and results are reported; experimental setup involved use of wind tunnel system; maximum head length was determined in terms of ratio of head length to lower stack diameter for various discharge velocities in series of wind tunnel tests; these maximum lengths should not be exceeded if discharge of effluent through gap is to be prevented. APTIC #4624.

187. Moore, D. J.
SO_2 CONCENTRATION MEASUREMENTS NEAR A 360 MW POWER STATION. Central Electricity Research Labs., Leatherhead, England. (Presented at the Symp. on Chimney Plume Rise and Dispersion, Oct. 7, 1966.

Surface patterns of SO_2 readings from a 360 MW generating station with 100M stacks are described. Existing methods of computation are shown to give reasonable estimates of observed 3-minute and hourly average concentrations when the atmospheric stability is neutral or unstable up to about twice the stack height. The presence of a stable layer below the stack top results in very low (often zero) surface concentrations. Stable layers above the stack top also give lower concentrations than occur in neutral conditions in most case, but in light winds or high winds the surface concentrations are sometimes increased. Average patterns of SO_2 in various categories of wind speed, stability and heat emission are presented, and their use in calculating long term surface concentration is discussed. APTIC #1933.

188. Nakagawa, S.
SULFUR DIOXIDE GAS IN EXHAUST SMOKE, ITS REMOVAL, RECOVERY AND UTILIZATION BY WET PROCESS. Japan Analyst, (Tokyo) 15(8):872-881, Aug. 1966.

Thirteen wet absorption processes for the removal of SO_2 in industrial exhaust are reviewed and evaluated in terms of efficiency, economy and recovery by-products. The author's special interest lies in recovering SO_2 in various useful compound forms such as ammonium sulfate and gypsum. A disadvantage of wet processes is that the temperature of exhaust gas decreases, resulting in the decrease of thermal buoyancy and exhaust velocity. The necessary booster power to make up for the difference in exhaust velocity is calculated to be 25.7 KW. assuming the temperature decrease of 80 C and certain typical conditions such as the composition of exhaust gas. Using the same assumed data as above, the effective height of 50 m smoke stack becomes 142.12 m. Sutton's equations give the maximum SO_2 concentration between 2360 m and 15,840 m depending on the air temperature gradient. From these calculations, the author corcludes that wet processes can be used profitably in controlling air pollution if they are combined with appropriate corrective measures. APTIC #3046.

189. Nonhebel, G.
CHIMNEY EMISSIONS AND IMMISSIONS: STANDARDIZATION OF FORMULA FOR ESTIMATION OF PLUME RISE AND GROUND-LEVEL CONCENTRATIONS. Int. J. Air & Water Pollution, 9:763-766, 1965.

Standardization, with definition of precision and limits of application, assists both technologists and laymen in understanding, time and money. Preparation of a Standard is a valuable discipline for research workers and highlights essential factors.

190. Olotka, F. T. and J. N. Brogard
THE COMPUTER AS A TOOL IN STACK GAS CALCULATIONS. Preprint. (Presented at the 60th Annual Meeting, Air Pollution Control Association, Cleveland, Ohio, June 11-16, 1967.)

A computer program has been developed for determining ground level concentrations of contaminants leaving a stack, in order to allow more rapid calculation. Its purpose is to facilitate the sizing of stacks and a study of downwind effects in a given area. Variations in ground level concentration, wind speed, stack height and downwind distance can be shown in detail. The combination of these variables is discussed. The program and a sample calculation are presented along with tabulated results. Program modifications to calculate the lofting effects and point of maximum ground level concentrations are also covered. APTIC #6416.

191. PERMISSIBLE IMMISSION CONCENTRATIONS OF HYDROGEN SULPHIDE. VDI (Verein Deutscher Ingenieure) Committee on Air Purification, Sub-committee on effects of Hydrogen Sulphide of the Committee on Effects of Dust and Gas. p. 15. Apr. 1960.

Contents: Permissible Immission Concentrations; Occurence of Hydrogen Sulphide - Occurrence in Nature, Occurrence in Technical Installation; Properties of Hydrogen Sulphide: Effect of Hydrogen Sulphide - Effect on Man, Effect on Animals, Effect on Plants; Exposure Limits. APTIC #0022.

192. PERMISSIBLE IMMISSION CONCENTRATIONS OF SO_2 . (Maximale Immissions - Konzentrationen (MIK) Schwefeldioxyd). VDI (Verein Deutscher Ingenieure) Kommission Reinhaltung der luft, Dusselforf, Germany. p. 18. Nov. 1961.

The maximum exposure limits of SO_2, its effects on humans, animals, and plants were discussed. The provisional tolerance limits for SO_2 are determined as half-hour mean values and range from 0.5 mg/m^3 (continuous exposure value) to 13.0 mg/m^3 (permissible work station value.) APTIC #6575.

193. PRESERVATION OF AIR PURITY AND THE PRODUCTION OF POWER. (Maintien de la Purete de l'Air et Production d'Energie.) Centre Interprofessional Technique d'Etudes de la Pollution Atmospherique, Paris, France. (Rept. No. CI 306) C.I.T.E.P.A. Doc. No. 24) 1967.

After a joint meeting of three German and three American experts on air pollution from large boilers and other sources, the problem of pollution was discussed with representatives of the Ministry of Labor and Social Affairs and the owners of large boilers in the State of North Rhine-Westphalia, in West Germany. The differences in approach, the climatic conditions, the size of the country, and the type of regulatory authority were explored. Various controls were investigated such as the use of high stacks, low-sulfur fuels, sulfur dioxide removal, and electrostatic precipitators. There is a short discussion of smog formation in California by photochemical action. In Germany, federal law governs the regulation of air pollution. Also in Germany the regulations cover individual parts of the installations, while in the United States the main consideration is the concentration of the pollutant in the ambient air produced by the installation. While investigations into the elimination of pollution continue, reliance on high stacks is suggested. APTIC #6781.

194. Price, J. T.
CHIMNEY FLOW IMPROVEMENT. Power Engr., 71(9):52-55, Sept. 1967.

Deflectors can be used to produce satisfactory flow and also reduce draft losses. Cold flow air model studies of the Colber Unit 1 and Bull Run Unit 1 are described to determine the effect of chimney geometry on plume rise characteristics. Addition of a vaned deflector to the 500-ft Colbert Unit chimney resulted in elimination of eddies and reduction of chimney draft loss by 0.7 in. of water. In the 800-ft Bull chimney, tests without hoppers revealed that the jets issuing from the breechings established an erratic spinning action in the chimney and that the alternating spinning motion was accompanied by random pressure pulsations which were reflected throughout the draft dystem. Use of a vaned deflector led to a reduction in draft loss of 0.3 in. of water. Without ash hoppers and without a deflector structure, this chimney was characterized by periodic pressure pulsations and flow was considerably more stable, but draft loss was increased by 0.1 in. of water. When the deflector was used without hoppers, reduction in draft loss was 0.5 in. of water. Flow patterns differed radically for the two chimneys, although both were similarly shaped and effluent entered through the bases. For the Colbert chimney, four vertical eddies were formed, while for Bull Run the spinning-type flow developed. Studies of the effect of chimney outlet shape upon velocity and dispersion indicate that a cylindrical outlet produces a higher average velocity with less radial spreading than a venturi shaped outlet. APTIC #9413.

195. PROVISIONAL METHODOLOGY FOR COMPUTING ATMOSPHERIC DISPERSION OF WASTE ASHES AND SULFUROUS GASES FROM POWER STATION SMOKESTACKS. (Vremennaya Metodika Raschetov Rasseivaniya v Vybrosov (Zoly i

Sernistykh Gazov) iz Dymovykh Trub Elektrostantsiy.) Teploenergetika (Transl. No. CI 207, Doc. Information Rept. No. 20) (7): 89-92, July, 1964.

Presented herewith is a translation of a Russian study. The method proposed is based on theoretical and experimental work carried out in the vicinity of a large thermal power station. It is valid for the calculation of dispersion of pollutants, determination of the necessary height of smokestacks; and for attaining normalized values of ground-level concentration of such pollutants. The report explains how to apply the formula defining maximum concentration and how to select the various factors involved. A graph is proposed which gives -- in terms of maximum concentration at a given distance -- the value of the concentration of pollutants at other points, and, finally, a method is described for calculating a minimum height of smokestacks compatible with the authorized limits of concentration of waste products in the atmosphere. Taking up a specific instance -- that of a certain power station located in the Ukraine -- an example is given of the practical application of this method in calculating the maximum concentration of noxious impurities at ground level. APTIC #2953.

196. Sartor, J. D. and R. R. Rapp
DRAG COEFFICIENTS OF SMALL, IRREGULAR PARTICLES. RAND Corp., Santa Monica, Calif., Engineering Division. Oct. 30, 1959. 15 pp. (Rept. No. P-1830).

The results of several laboratory tests conducted with spherical and irregularly shaped particles are presented. These measurements were made to clarify the law of fall of irregular particles in the range of Reynolds number from 0.035 to 3.5. Over this range of Reynolds numbers, the Goldstein formula yields a good approximation to the drag coefficient of irregularly-shaped particles as well as to perfect spheres. For extremely jagged particles in the range of Reynolds numbers from 0.035 to 0.35, the drag-coefficient estimate from the Goldstein formula may be 20% lower than the true drag coefficient. No evidence has been found for the extremely low drag coefficients shown by Krey (1932) in the region of Reynolds numbers from 1.0 to 3.0. Results of the experiments are presented in Tabular form, and are compared graphically with theoretical values. APTIC #5052.

197. Schultz, H. A.
DETERMINATION OF GASEOUS ORGANIC HALIDE TRACERS IN AIR BY POSITIVE ION EMISSION TECHNIQUES. (Presented to Am. Chem. Soc. Symposium on Air Pollution, Atlantic City, N. J., Sept. 1956.)

Dichlorodifluoromethane, Freon 12, shows definite promise as a tracer for use in the study of atmospheric diffusion. At atmospheric pressure and temperature, it is a colorless, odorless gas, non-corrosive and nontoxic. Its feasibility as a tracer was demonstrated by the study of the effluent from a stack, using the ionization method of detection. A commercial ionization-type halogen detector was modified, and special techniques were developed, so that concentrations down to 0.1 ppm. could be readily measured. Commercial detectors, which are built for qualitative work, vary greatly to sensitivity, and in general, tend to be unstable. The mechanisms responsible for the sensitivity of this type of detector are being studied, with the object of improving the stability and possibly also the sensitivity. A multiple step process is involved, so instability may arise in a number of different ways. Fortunately, it is possible to provide independent controls over a number of the essential steps.

198. Sherlock, R. H. and E. J. Lesher
DESIGN OF CHIMNEYS TO CONTROL DOWN-WASH OF GASES. Amer. Soc. Mec. Eng., 77:1-9, 1953.

Studies to determine the laws of behavior of stack gases as they flow downwind, and to prevent down-wash of these gases, have been in progress at the University of Michigan since March, 1934, when a project in this field was sponsored by the Commonwealth Edison Company of Chicago. That pioneer project was connected with the Crawford Avenue Station and was followed during the later years by other studies dealing with the extension of old plants and the design of stacks for new plants. The material presented in this paper was obtained almost entirely from recent studies sponsored by the Commonwealth Edison Company.

199. Short, W.
SOLIDS EMISSION IN RELATION TO RECENT LEGISLATION. Steam Heating Eng. (London), 37(432):28-37, Nov. 1967.

A review of solids emission in relation to recent legislation is presented. The control of solids emission both in regard to legal requirements and equipment available is discussed. The topics discussed are: oil firing, grit arrestors, chimneys, and additives. APTIC #8615.

200. Smith, M. E. and I. A. Singer
SAMPLING PERIODS IN AIR POLLUTION EVALUATIONS. Proc. Natl. Air Pollution Symp., 3rd, Pasadena, Calif., 1955.

Field sampling in relation to air pollution studies requires consideration of three factors: an analytical technique, selection of sampling locations, and the choice of appropriate time periods. However, sampling periods are almost completely disregarded in most studies. "Representative" or "appropriate" periods are normally specified, without any indication of the meaning intended. It is the thesis of the present paper that the selection of correct sampling periods can be of equal importance with instrumentation and location in air pollution evaluations. Analysis of a single, typical case taken from an earlier Brookhaven program illustrates the fact that sampling periods are extremely important in air pollution studies. It is clear from the data presented that errors of a factor of ten or more may arise from the choice of improper sampling period. APTIC #5579.

201. Smith, M. E.
THE REPRESENTATIVENESS OF LOCAL OBSERVATIONS IN AIR POLLUTION SURVEYS. Air Over Cities Symp., Cincinnati, Ohio, 1961.

The need for approrpriate meteorological data in the evaluation of air pollution problems is now generally conceded. The natural tendency is to use existing observational data whenever the material seems pertinent. In investigations by the Brookhaven Meteorology Group, data from a number of sources, including tower and surface observations, have been compared. Depending on the circumstances, both the differences and similarities are striking. Enough information is now available to indicate situations in which data may be validly transferred from one site to another and those in which transfer should not be attempted. Careful estimates of wind and stability distributions for sites with complex terrain may often by far superior to an inappropriate transfer to data. APTIC #3388.

202. Snowball, A. F.
INDUSTRIAL AIR POLLUTION - ITS MEASUREMENT AND CONTROL. Preprint. (Presented at the 3rd Annual Meeting, Pacific Northwest Section, Air Pollution Control Assoc., Vancouver, Brit. Columbia Nov. 2-4, 1965.)

Various methods, commercial equipment, apparatus, and tests for measurement and identification of solid and gaseous industrial pollutants at their source are briefly described. APTIC #1177.

203. Squires, A. M.
AIR POLLUTION: THE CONTROL OF SO_2 FROM STACKS. PART IV. POWER GENERATION WITH CLEAN FUELS. Chem. Eng., 74(26):101-109, Dec. 1967.

The technology of two-stage combustion processes for removal of sulfur from coal and residual fuel oil to be utilized in steam plants is analyzed. In two-step combustion a first gasification stage yields a flue gas containing hydrogen sulfide. From this 1st step elemental sulfur is recovered and the clean fuel gas is burned in a second combustion step. Various processes which might be adapted to this two-step combustion are considered in some detail. APTIC #8908.

204. Squires, A. M.
AIR POLLUTION: THE CONTROL OF SO_2 FROM POWER STACKS. PART II. THE REMOVAL OF SO_2 FROM STACK GASES. Chem. Eng., 74(24):133-140, Nov. 1967.

The technology, design and economics of systems for removing sulfur oxides and fly ash from power stations stack gases are examined. Dry or wet limestone or dolomite processes receive particular attention. The prospects for recovering sulfur byproducts competitively from stack gases are investigated. APTIC #8918.

205. Stone, G. N. and A. J. Clarke
POWER STATIONS AND CLEAN AIR. Central Electricity Generating Board (England). 1963.

This paper discusses the chimney emission problems presented by power stations and the techniques developed for dealing with them. Study of chimney plume behavior, instruments developed to assist in research, and research into dry sorption processes for removing SO_2 from flue gases, are reviewed. APTIC #2311.

206. Stratman, H. 1956.
SULFUR DIOXIDE EMISSION FROM A COAL-BURNING POWER PLANT WITH A VERY HIGH STACK. Mitt. Ver. Groskesselbesitzer, No. 40: 49-56, 1956; CA., 50: 9661, 1956.

Determinations of the SO_2 concentration at ground level around a power station with chimneys of 150 M. (490 ft.) height and an SO_2 emission of 0.84 to 1.02 tons/hr. carried out over a year, have shown that the max. concentrations were generally below 0.5 mg. SO/m^3, the limit above which damage to vegetation may occur. Very occasionally this max. value exceeded for short times. The max. concentration was found at a distance of between 1500 and 3500M. from the chimney base; the experimental values agreed well with calculated values. The SO_2 concentration varies in cycles with a max. in January and a min. in July. The measurements also showed that the increase of SO_2 concentration caused by industrial plants and populated areas is of the same order of magnitude as that caused by power stations.

207. Sutton, G.
DISPERSAL OF AIRBORNE EFFLUENTS FROM STACKS. Brit. Chem. Eng. (London), 1:202-205, Aug. 1956.

In designing stacks for the dispersal of gaseous or particulate pollution the rule is: make the stack as high as possible and conserve heat. The reduction of concentration at ground level is proportional to the added heat, and inversely proportional to the height of the stack and the cube of the wind speed. In high winds, there is little advantage to be gained by adding heat, but in these circumstances the high wind reduced concentrations to an acceptable low level by straight-forward dilution. The main difficulty in dealing with pollution arises when the wind is low.

208. Takaoka, Y.
STANDARD FOR STACK GAS EMISSION. Text in Japanese. J. Jap. Petrol Inst., (Tokyo), 7(2):100-102, Feb. 1964.

The regulations for air pollution established in 1962 are studied from the point of view of the petroleum industry. The regulation calls for a maximum allowable concentration of dust from heating furnaces of 0.7 g/m^3 and from catalytic regenerative furnaces of 1.0 g/m^3 both using a cyclone for dust collection. The regulated concentration of SO_2 or SO_3 gases is 0.28%. The relation between SO_2 production and the quantity of excess air required to burn liquid fuel is graphed.

Data for gaseous fuels are given indicating that for crude petroleum gas and for the gas given off by apparatus designed for improving the quality of gases, an air pollution problem does not exist, but the gas emitted from contact decomposition equipment or H_2S-producing equipment causes problems. The diffusion theory is explained briefly with a graph showing the relation between wind velocity and concentration and includes a table showing the relation between velocity, temperature, and effective chimney height for an actual height of 45.7 m. APTIC #7491.

209. Third, A. D.
THE AIM OF CHIMNEY DESIGN. Eng. Boiler House Rev. (London) 82(5):124-128, May 1967.

The enforcement of the provisions of the Clean Air Act of 1956 has led to an over-all increase of chimney heights. Developments in fuel technology and boiler design have resulted greater combustion efficiencies with reductions in flue gas temperatures. The acid dewpoint which occurs at 270 F is important since below this temperature, the sulfuric acid condenses out and the corrosive effect becomes more intense as the temperature drops. In addition to attacking the chimney, the 2 to 4% sulfur trioxide agglomerates with carbon and ash and forms a skin on the chimney surface which eventually breaks away in the form of flakes which are then carried upward in the gas stream. Eventually these flakes fall to the ground as acid smuts within 3 to 400 yards of the chimney bases and can be detrimental to property and health. One approach to the problem is the use of double-skinned chimneys formed of mild steel with aluminum foil insulation. The air gap between the steel and aluminum of 5/8 in. is sufficient to raise the metal and gas temperatures at the top of the stacks to prevent acid condensation. The use of helical strakes on the outside of tall chimneys tends to prevent oscillation in high winds. APTIC #6157.

210. Winkelman, L. A.
EMISSION STANDARDS FOR THE CONTROL OF SOLID PARTICLES, A NEW APPROACH BY NEW JERSEY. J. Air Poll. Control Assoc., 14(11): 441-4, Nov. 1964.

Existing chapters of the New Jersey Air Pollution Control Code are described, followed by an explanation of a proposed new chapter to control emissions of coarse solid particles and fine solid particles from industrial processes. The chapter is designed to limit dustfall of coarse particles off the premises of the emitter to 200 tons per square mile per year, and the methods used to relate this criterion to stack emissions are explained. Fine particles, suspended in the air off the premises, are limited to 0.615 milligrams per cubic meter during average weather conditions. Measures taken for the protection of buildings, where the plant-property line is less than 10 stack heights from the base of the stack, are described. APTIC #4524.

211. Winterberg, W.
CORRECTLY MEASURED CHIMNEYS -- ALSO A CONTRIBUTION ON THE PURIFICATION OF AIR. (Richtig bemessene Schornsteine -- auch

ein Beitrag zur Luft.) German VDI (Ver. Deut. Ing.) Ber. (Dusseldorf), No. 117, p. 19-28. 1967.

The history and derivation of formulae for the diameter of chimneys are outlined. An equation for the cooling of exhaust gases is derived, and a nomogram for that equation provided (giving relationships between chimney diameter, chimney material, heat transmission coefficient, the generated volume of gas, and the difference between the temperature of the gas inside the chimney and that of the external air). Other equations are derived which are related to prevention of condensation in chimneys. Calculations are made pertaining to single-stack chimneys. Diagrams are provided for the regulation of wall temperature in three-stack chimneys, for the cooling of the exhaust gases in three-stack chimneys after burning of oil, for a comparison of the gas flow in round and in square chimneys, and for a 3-dimensionable picture of the relationship between chimney height, chimney load, and "free" movement. APTIC #8726.

212. Wipperman, F. and W. Klug
A PROCEDURE FOR DETERMINING MINIMUM CHIMNEY HEIGHTS. (Ein Verfahren zur Bestimmung von Schornsteinmindesthohen.)
Intern. J. Air Water Pollution 6:27-48. Ger. (Tr.) 1962.

A procedure is given which makes it possible to determine the minimum height of chimneys such that as given maximum allowable concentration at ground level is not exceeded. The first part of the paper deals with the use of nomogram, while the second gives the theoretical basis of these nomograms; in particular, derivation of the formula used and determination of the meteorological parameters contained in it are given. APTIC #4615.

ADDENDUM

213. TALL STACKS, Air Engng., 10:15, April 1968.
Duquesne Light Co. 1968.

A 759-ft. concrete chimney will be erected by the Rust Engineering Co., division of Litton Industries, for Duquesne Light Co.'s Cheswick power station on the Allegheny River. The stack will discharge gases into the upper atmosphere, so that they will be carried long distances, gradually being diffused into the atmosphere. Any gases returning to ground level at any point will be safe under established standards. The chimney, 58 ft. in diameter at base and 27 ft. at the top, will contain 4,175 cu. yds. of concrete and 275 tons of reinforcing bars, plus a steel liner. It will serve the coal-fired boiler of the 570,000 kilowatt plant being built by Duquesne Light at Springville, Pa.

214. THE INVESTIGATION OF ATMOSPHERIC POLLUTION 1958-1966. (THIRTY-SECOND REPORT). Ministry of Technology, London, England, Warren Spring Lab. London, Her Majesty's Stationery Office, 1967, 146p.

A broad review of emissions, abatement processes, dispersion, weather effects on pollution, the national survey of smoke and sulfur dioxide, trends in pollution, grit and dust fall, and measurement methods is presented. Research now in progress in the United Kingdom is described and the research location and project officer for each project is given. APTIC #8895.

U. S. GOVERNMENT PRINTING OFFICE : 1969—395-976/13